THE DESIGN AND IMPLEMENTATION OF SERIOUS GAMES FOR DRIVING AND MOBILITY

Ph.D. Thesis

By

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Declaration

I, Pratheep Kumar Paranthaman at this moment declare that the thesis report titled "The Design and Implementation of Serious Games for Driving and Mobility" is the result of my scientific and research activities carried out during the Ph.D. course (2014 - 2017). The use of other authors works (ideas, concepts, tables, and figures) are cited within this document.

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Abstract

The automotive and transportation sectors are showing consistent improvements in trends and standards concerning the safe and convenient travel of the road users. In this growing community of road users, the driver performance is a notable factor as many on-road mishaps emerge out of poor driver performance. In this research work, a case-study and experimental analysis were conducted to improve driver performance through the deployment of serious games. The primary motive of this work is to stimulate the on-road user performance through immediate feedback, driver coaching, and real-time gamification methods. The games exploit the cloud-based architecture to retrieve the driver performance scores based on real-time evaluation of vehicle signals and display the outcomes on game scene by reflecting the game parameters based on real-world user performance (in the context of driving and mobility).

The deployment of games in cars is the topic of interest in current state-of-the-art, as there are more factors associated with it, such as safety, usability, and willingness of the users. These aspects were taken into careful consideration while designing the paradigm of gamification model. The user feedback for the real-time games was extracted through pilot tests and field tests in Genova. The gamification and driver coaching aspects were tested on various occasions (plug-in and field tests conducted at 5 European test sites), and the inputs from these field tests enabled to tune the parameters concerning the evaluation and gamification models. The improvement of user behavior was performed through a virtuous cycle with the integration of virtual sensors to the serious gaming framework. As the culmination, the usability tests for the real-time games were conducted with 18 test users to understand the user acceptance criteria and the parameters (ease of use and safety) that would contribute to the deployment of games. Other salient factors such as the impact of games, large-scale deployment, collaborative gaming and exploitation of gaming framework for 3rd party applications were also investigated in this research activity.

The analysis of the usability tests states that the user acceptance of the implemented games is good. The report from usability study has addressed the user preferences in games such as duration, strategy and gameplay mechanism; these factors contribute a foundation for future research in implementing the games for mobility.

Acronyms and Definitions

Acronym	Expansion
ADAS	Advanced Driver Assistance Systems
ASTA ZERO	All Service Test Area
CAN	Controller Area Network
CONAV	Collaborative Navigation
CPTO	Collaborative Public Transport Optimization
CRF	Centro Ricerche FIAT
DG	Driver Game
EFP	Eco-Friendly Parking
FT	Fluid Traffic
GD	Green Drive
HMI	Human Machine Interface
ITS	Intelligent Transportation Systems
IVC	Inter-Vehicle Communication
IVIS	in-vehicle information systems
PG	Passenger Game
S&L	Snake and Ladders
SD	Safe Drive
SG_CB	Serious Games and Community Building
SGs	Serious Games
UI	User Interface

Chapter 1: Introduction

The intelligent transportation systems (ITS) have contributed many advancements (road infrastructures, in-vehicle units, communication and sensing technologies) to automotive and transportation sectors. However, it is necessary to ensure the safe and convenient transportation of road users, because with the growing number of problems in transportation domain the outcomes have resulted in road accidents, traffic congestion, and environmental pollution. From the problems in road environment, the road accidents have become the predominant reason for causalities and economic loss; around 1.3 million people die every year in road accidents [1] [2]. The pollutant gas emission from road transport causes environmental degradation and contributes to serious health issues [3] [4] [5]. When analyzing the cause of all these problems, the most of it is associated with human factors and specifically, the driver behavior [6] [7]. Certain characteristics of driver behavior, like over speeding and aggressive driving holds a significant contribution towards road accidents and risky events [8] [9] [10] [11]. Secondly, it is the driver’s inattentiveness, and distraction that leads to diversion from the primary driving task, and this can incur vehicle collision [12] [13] [14]. With recent trends in ITS, the measures are growing to leverage the problems in transportation industry [15], and there is a broader scope for research in this sector to analyze more robust methods to ensure green driving and road safety.

From studies [16] [17] [18], it is evident that training drivers or influencing driver performance can have positive impacts towards the safety factor and effective driving. For training drivers and to induce the behavioral aspects, the serious game concept was exploited [19] in this research activity to provide a gamified environment for road users to foster green and safe driving. Serious games (SGs) are a purpose-based tool and specifically used for training [20] [21] [22]. The SGs are a prominent tool in conveying information through an engaging medium. The user engagement and adaptation towards the gameplay creates behavioral impact in players and also acts as a motivation factor to achieve goals and improve skills [23] [24] [25]. Designing a serious game is highly challenging as it should seal the information and entertainment in the same unit. The core of serious game should be equally balanced between the information and entertainment, if there is an imbalance in this, then the informative content becomes trivial. Usage of instructional design (application of technology and multimedia) in crafting a serious game framework can be a significant aspect of a serious game design [26].

The incorporation of instructional design and serious games can enable a higher level of learning outcomes, as the design will involve necessary game characteristics (competitions, goals, challenges, etc.) and learning objectives [27].

The use of game elements in non-gaming context is termed as "*Gamification*" [28], and this methodology can be implemented to reinforce user involvement. When developing games for infotainment, it is necessary to consider the properties of the game such as ease of use, feedback mechanism and an effective strategy (depending on the goals). Utilizing games in transportation is one such kind, the games for mobility may sound daunting at the beginning because of complexities that are associated while driving. However, by considering the potential benefits of serious games and gamification elements, the approach of using games for mobility will be a new dimension and can yield more positive outcomes in altering the driver behavior. The scope of research in this sector is more because very limited work has been performed to analyze the impacts of games in automotive and transportation sectors.

The Internet of the Things(IoT) forms a substantial part in integrating technologies and forming a network of connected things. It has been stated that by 2020 there will be 34 billion devices connected to the internet and around $6 trillion will be spent on IoT solutions over next couple of years [29] [30]. The need for connectivity and smart mobility solutions have gathered importance for addressing the growing number of problems in the transportation sector. From the analysis of [31], it is expected that 381 million connected cars will be on the road by 2020 [31]. The combination of collaborative mobility solutions in SGs architecture can encourage more users to participate in games and compete with their peers to exhibit better skills. The concept of collaborative mobility will be a supporting factor for SGs framework because the users can have a comparative analysis of their performance with other users in a zone/city. Apart from the comparative analysis, the users can share various information to their networks, such as problems in road networks, location sharing and analysis of performances as well.

By wrapping the game elements, with the criterion for better driving performance and smartphone capabilities into a single unit, a basis for driver performance improvement in real-world driving contexts can be formed. Taking into account of the key issue (driving behavior) in road safety and transportation sector, the collaborative gaming framework termed as *Serious games and community building(SG_CB) application* was developed for the road users to captivate the green and safe driving performance. The SG_CB comprises of a centralized cloud architecture with the suite of serious game typologies for catering various types of road users.

The SC_CB smartphone application provides the facility to visualize the gameplay status, real-time gaming, performance statistics, driver coaching and basic social networking. An in-car driver performance evaluator has been deployed to assess the driver behavior based on the vehicle signals. The evaluators act as virtual sensor unit to extract the user performance from the real-world, and the extracted performance evaluation results are sent to the cloud server frequently, and the scores are computed based on average performance. The user can participate in various games by subscribing to the particular game/competition. Based on the user performance scores the games evolve with associated strategy. For example: in a competitive approach the user scores are compared with their peers, and at the end of the competition, the ranks are generated based on the secured scores. At the end of the competition (according to specified time slot), the user can visualize a detailed report of performance (scores, rewards, events, etc.,). The evaluation consists the continuous and event-based assessment modes, which the users can determine based on their preference.

The further sections of this research document are organized as follows: the description starts with Chapter 2: Related work, which explains the state-of-art analysis of existing architectures and methodologies. In Chapter 3: Research problems and Hypothesis, the research problems and scope of research are highlighted, and the major focus is on the existing problems and set of research questions to address the issues in the current paradigm. The Chapter 4: System architecture and components – deals with various components of SC_CB system architecture and game designs. Chapter 5: Implementation and deployment of prototype designs - describes the implementation and deployment of the game prototypes with further explanation on the test cases. The description of various field tests and usability tests are represented in Chapter 6: Field Tests and Deployment Scenarios. Finally, the user studies and analysis are represented in the experimental analysis section - Chapter 7: Experimental results and analysis.

Chapter 2: Related work

The case study of games in automotive industry comprises few other dimensions such as serious games in other domains, collaborative mobility solutions and initiatives taken by car manufacturers and insurance companies. As serious games are used as a major component in this system architecture, it was necessary to understand the impacts and deployment of serious games in various domains. Apart from impacts, the key outcomes of serious games can be derived to formulate a solid system core and game mechanics to build SGs in the automotive sector.

2.1. Serious games in various domains

As stated earlier, the serious games are a purpose-based tool and are primarily used for user motivation and learning tasks. The user motivation is the main concern, as most of the applications oriented to infotainment focus on the system core with modules that would enhance better user motivation. The experiment conducted by [32] used the game elements (badges, scores, and leaderboard) in a serious game application – "Aqua Republica" and studied the effects on the user performance. The tests were conducted to estimate the performance outcome between the gamified and non-gamified groups to ensure the impacts of game elements, and the results proved that the performance exhibited by the gamified group was higher compared to the non-gamified group. The use of gaming elements in non-gaming situations is gaining more attention, and this process is effective in educational and training activities [33] [34] [35]. The learning/training programs (MOOCs and online tutorials) involve adequate user participation for achieving the necessary outcomes of the training program. In this particular instance, the use of traditional instruction based training will not leverage the learning outcomes and can eventually lead to the non-cooperation of the users [36] [37]. To enhance better learning outcomes, the organizations and training academies [38] [39] are in the process of adapting the game-based learning techniques for conducting the training or knowledge transfer programs [40]. The game-based learning techniques deliver the fun and informative content together. Thus the users tend to understand and experience the informative content through gameplay or an interactive medium [41] [42] [43].

The exploitation of serious games in organizations has not only focused on instructive mechanisms but also in acquiring new skills and techniques, such as the - IBM's INNOV8 BPM, which is a simulation-based serious game for training the students and employees to acquire new skills [44] [45] [46].

The applications such as Duolingo and Memrise aims to teach languages to new learners through interactive gameplay sessions comprising levels, scores, bonus, leaderboard and chat option [47] [48]. The Duolingo application with game elements and learning metrics has gained 120 million users around the world [49]. The use of serious games to teach programming language was adopted in PLAYLOGO 3D video game [50], the game mechanics involved an interactive environment to teach basics of programming for the children aged between 6-13. Similarly, the concepts of object-oriented programming were taught through java exercises in a 2D game called “Ixquic” [51], the target goal was to equip the user with necessary programming skills through the engaging gameplay. SGs are also used in treating and diagnosing the medical illness conditions such as Attention Deficit Hyperactivity Disorders (ADHD) [52] [53], Post Traumatic Stress Disorders [54] and chronic illness [55] [56] [57].

2.2. Driver support systems and collaborative mobility solutions in automotive sector

The issues concerning transportation such as traffic congestion, accidents, and other environmental challenges are a solid hindrance for making travel experience green and safe for the road users. With increasing number of vehicles and road users, the intensity of traffic congestion has become more in metropolitan cities [58]. The growth in traffic congestion and density have made the traffic control management at intersections more tedious [59]. The advancement in automotive and transportation systems have given more space for the researchers to handle the issues related to smart mobility. Some existing systems in the field of intelligent transportation systems have addressed the management of traffic control systems in intersections through Artificial Neural Networks [60], genetic algorithm [61] and fuzzy logic [62]. But, as traffic management depends on decision making and the proper correlation between the intersections, there need to be more sophisticated models to address this aspect. For this purpose, the Markov Decision process (MDPs), Reinforcement Learning (RL) and approximate dynamic programming (ADP) were used [63]. The traffic control and safe mobility depend on managing intersections and traffic signals efficiently and few more aspects are to be addressed like: driver behavior, vehicle safety, and environmental factors.

It is about 85% of accidents are caused due to driver behavior [64], and this factor stands as a major threat to safe mobility.

The advent of advanced driver assistance systems (ADAS) support the road users in various aspects of mobility (driving, parking, and navigation). Deployment of in-vehicle systems for coaching drivers can serve the purpose of enhancing the safe driving behavior [65].

Apart from coaching driver, the safe Human-machine Interface (HMI) can be exploited to manage vehicle and assist drivers in maintaining the green and safe driving pattern. Adaptive cruise control system [66] is commonly used to manage the velocity of the vehicle to maintain nominal distance, and these cruise control systems were initially destined to improve safety and comfort [67]. The driver assistance systems could be provided with more amount of data from surroundings for executing sophisticated tasks to assist drivers. The data extracted from in-vehicle information systems(IVIS) assist the driver in decision making, safe driving, and managing the traffic conditions [68]. IVIS also monitors mechanical and environmental circumstances [69], as this information could be used to intimate the drivers about on-road hazards. One such approach to collision warning system, which performs object detection and perception through sensors and cameras to alert drivers regarding the intrusions or obstacles on-road [70]. Vehicles can communicate with each other for establishing cooperative information sharing, and this aspect of inter-vehicle communication (IVC) is expected to be deployed in all vehicles [71] [72].

Road environments are filled with rapid happenings, and due to this, drivers experience perceptional problems in responding to emergency warnings, the use of IVC can reduce the delay in propagating alerts to drivers [73]. The concept of IVC has provided good scope for automobile manufacturers for the development of Vehicular Ad-Hoc NETworks (VANETs) [74] [75]. Considering the exchange of information between vehicles, the privacy of communication must be taken into account [76] and some existing privacy solutions [77] [78] [79] can be adopted for safe vehicular communication. By unifying the assets of intelligent transportation systems and smart devices, the transportation elasticity and safety can be achieved by forming a collaborative network of road users.

The mobile wireless systems will facilitate the formation of intelligent infrastructure systems by combining vehicles, road users, and infrastructure as a connected unit [80]. The parking space management has become a complex issue, where the drivers searching for vacant parking space contribute to 30% of traffic congestion [81]. Thus, the process of forming a collaborative approach can address the issues related to parking space management, traffic congestion, on-road hazards, collisions and environmental aspects to a greater extent. The next generation of intelligent transportation systems will share information for managing the safe gaps, braking operations and optimal driving [82].

2.3. Games in automotive domain and driver performance assessment systems

Driver behavior assessment through in-car models is getting more prevalent, and in-car driver support models have a direct association with drivers. The in-car models are used to assist drivers in various tasks involving contextual, behavioral and for the betterment of performance as well. It is stated that the driver support systems have more tendency to eliminate the on-road impacts and fatalities caused due to driver behavior [83]. For, the purpose of estimating driver performance, the approaches involving the extraction of vehicle signals through CAN (controller area network), or smartphone sensors are used [84] [85] [86] and later these vehicle signals are associated with driver performance. Installation of sensors and cameras to track driver intention and environment data analysis are also performed [87] [88] [89]. Some projects have used machine learning approaches for estimating driver behavior, in [90] the driver behavior model was developed for understanding lane change decisions, pedal-operations, and driver frustration through statistical signal processing and machine learning. Neural networks have been deployed to model the driving style of different drivers and to optimize the neural networks, a multi-objective genetic algorithm was used [91].

Certain aspects such as visual illusion and misrecognition can cause road accidents [92], and the driver support systems are used to overcome these problems. In [93], a Smart-Eye was used to share real-time on-road events (traffic and accidents) into text, audio, and video information to other vehicles to prevent accidents/collisions. In the case of an accident, the Smart-Eye system triggers the details of the accident to insurance companies, relatives, hospital authorities, etc. By installing the in-car cameras and sensors, the factors (drowsiness, fatigue and visual distraction) associated with driver behavior can be closely monitored and can be used for alerting drivers in case of emergency.

In [94], the driver drowsiness detection system to monitor the drowsy state of the driver was implemented by modeling the driver-specific blinking patterns, and the system generates a warning based on the estimation results of drowsiness detection. From the studies conducted by [95] [96], revealed that the driver behavior is safer when being monitored and instructed with feedback. Also, the feedback systems can induce knowledge about the on-going circumstances and impact the behavioral aspects of the driver in maintaining optimal driving behavior. The driver feedback modality contributes to discarding inappropriate events and of how to avoid such events in future as well [97]. By real-time feedback, the driving style associated with safe driving and fuel efficiency can be increased significantly [98] [99] [100].

***Figure 1**: Online performance report of drivers in Carwings app [101]*

Smart driving initiatives are taken by car manufacturers, which enables the driver to track and share driving behavior with peers. Carwings is one such application representing fuel consumption status, money spent vs. buying gas and a comparison of performance with peers [101].

Car2Go, a car-sharing service promotes gamification by grading drivers for environmental friendly driving habits based on acceleration and braking behaviors [102]. Apart from these evaluations and driver behavior models, the HMI (human-machine interface) plays a significant role in driver support systems.

The better design requirements should include an effective Human-machine Interface in vehicle aesthetics [103]. The factor of safety and driver distraction are major considerations for safe HMI design, as an intrusion of the driver in secondary tasks can lead to accidents [104].

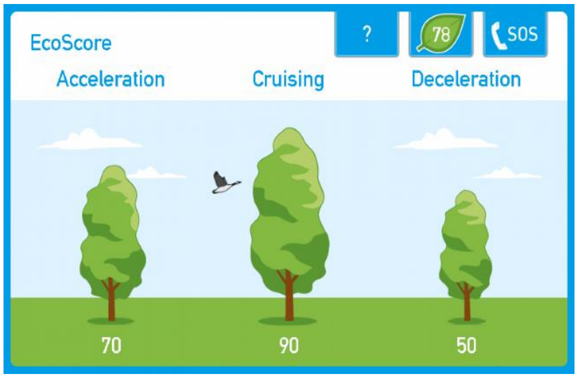


***Figure 2**: Driver's effectiveness report from car2Go application [102]*

The project I-GEAR aims to improve the driver behavior through incentives, and this was targeted to induce an optimal driver behavior to reduce the traffic congestion [105]. I-GEAR combines the serious games, pervasive games, and location-aware traffic management systems to motivate users in exhibiting a particular behavior to manage the traffic jams. The gaming approach in I-GEAR promotes collaborative and competitive mechanisms to the drivers. Some games focus on captivating eco-friendly driving behavior, for example, the iCO_2 game is a networked game that uses Distributed Virtual Environments (DiVE) networking framework [106]. The iCO2 supports the eco-driving abilities, where the player needs to accelerate and decelerate smoothly to achieve good scores. Similarly, in work carried out by [107], the players were involved in a virtual gaming environment, and the serious game concept was used to induce eco-driving training. The results indicated the positive impact of serious games in enhancing the eco-driving skills of the players with a significant reduction in CO_2 emission.

From the state-of-art analysis, there are numerous approaches, which are addressing the issue of road safety factors from the viewpoint of driver behavior. By, providing necessary knowledge about the driving pattern, a training aspect can be induced in drivers and eventually, training of drivers can improvise green driving behavior [108]. For training and enhancing driver performance, serious games concept can be used. As, serious games can influence the behavioral aspect of players (such as improvising skills, decision-making abilities, etc.,) [109] [110].

The use of gamification process for improvising driver behavior can benefit the road users in rectifying harsh maneuvers, understanding performance outcomes and to constantly maintain optimal driving behavior.

2.4. Initiatives by car manufacturers and Insurance companies

Gaming in-car corresponding to the surrounding environment is an emerging research field, and the relevant design space is showing significant possibilities and challenges [111]. The work carried out by [112] reported on the results of a series of ideation workshops with the goal to explore game designs that promote stressless-ness and wellbeing in the automotive context, also exploiting context information, such as traffic and driver style. An interesting concept for a collaborative game (nICE) [113], which was designed to be played by all occupants of a car (including the driver), during their journey. A test of the implementation made in collaboration with BMW, under real-world conditions provided promising results.

However, the authors found that the users were focused on the game, neglecting the roadside environment. The attempt to draw the players' attention towards the points of interest located nearby through an observation mini-game was unsuccessful. Moreover, the evaluation raised the issue of driver distraction.

The automakers are using "*gameful design*" to provide a simple gaming interface for the users to improve the standards of eco-driving and fuel efficiency [114]. There are even indicators that assist drivers in managing fuel and other aspects, the Honda's eco assist system is one amongst them [115] [116], which facilitates the drivers to understand how their driving habits affect the fuel economy. The Ford's SmartGauge with Ecoguide provides a supporting feature to assist drivers in changing the driving style to attain maximum fuel efficiency [117] [118] [119].

***Figure 3**: Ford smartguage with Ecoguide[117]*

The small changes in driving style can improve fuel efficiency. In Ford's SmartGauge, the LCD on either side of speedometer displays the outcomes of driving, where the EcoGuide represented the leaves and vines as a reflection of driving style and based on these outcomes the driver tends to adjust the driving style for better fuel efficiency.

The five key challenges for in-car game design for children: different expectations by parents and children, undesired detachment, short interaction span, poor GPS reception, and motion sickness [120]. Ford Europe has recently announced its "Smart Mobility" experiments in London to better understand the driver behavior and help volunteers take steps towards improving it, using methods, not unlike those used by fitness apps [121].

The data collected includes steering angle, gas pedal position, and brake pedal pressure. Using vehicle signals information, Ford was able to give each volunteer a daily “driver score,” along with tips to improve it. The declared business cases include cost reductions for car rental, sharing, and insurance. Development of in-vehicle infotainment systems related to car data is getting interest as testified by the recent General Motors “next generation infotainment software development kit” initiative, that allows developers to build and test applications with emulated vehicle behavior and more live data [122]. Exploitation of vehicle data (Speed, RPM, Acceleration, etc.,) can provide more insight into driver behavior, and nowadays insurance companies (for example Allstate, Progressive, Metromile and Real Insurance) are using vehicle data to customize the premium plans to track the fraudulent discount claims [123]. The driving data is collected through a telematics device [124] (it is estimated that by 2020, the telematics policies will expand its schemes to insure 100 million vehicles [125]) or by smartphone sensors [126] [127] and later this data is used to determine the Usage-based plans (UBI) such as Pay as You Drive (PAYD) [128], Pay How You Drive (PHYD) and Pay per mile insurance schemes [129].

2.5. Privacy concerns and user choices

With all these advancements, the vehicle data collected and processed by insurance companies has raised an issue on privacy. Where some users are not willing to provide their vehicle data to the insurance companies, but still 35% of people are willing to share their details and participate in usage-based plans for a compensation in schemes [144]. So, from the test conducted with 1000 respondents [144], the 37% mentioned that they would not participate in insurance plans for their personal reasons and however the people who accepted to participate did expect some substantial savings. Still the responses did inform about the benefits of these insurance plans towards users and also it is way for the insurance companies to manage the fraudulent claims and inform the drivers about their driving behavior. More specifically the Progressive Insurance [144] [145] [146], has mentioned that they don’t collect the GPS data from the users, so they will not have any trace about the user’s location and they only track the vehicle signals. The upcoming policies can concern more towards the vehicle data such as speed, brake, RPM, etc., rather than collecting sensitive information like user’s location and whereabouts.

Chapter 3: Research problems and Hypothesis

From the analysis performed on the existing systems in the fields of the automotive sector, driver support systems, and gamification research, still, there is a drawback in the integration point between the user participation in games and improvement in driver behavior. The wide scope of research and broader analysis are needed to achieve the deployment of games in the automotive industry, with more focus on the aspects of safety, user involvement, game logic, feedback system, real-time gaming, interface management and collaborative systems.

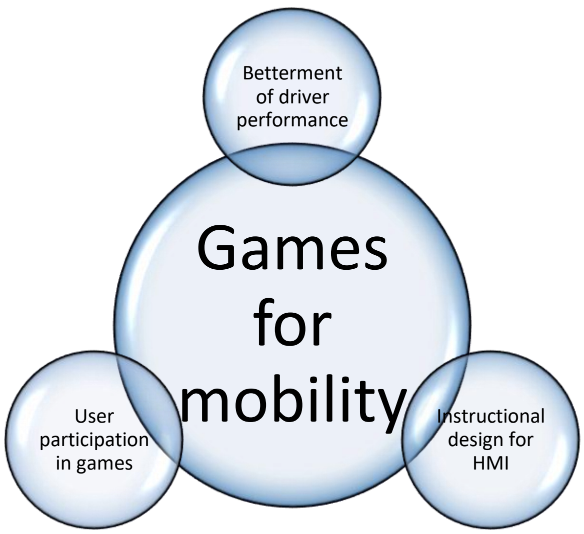


Figure 4: *Point of intersecting factor concerning the games for mobility*

One reason for the drawback is because the transportation and the automotive industry are more sensitive with regards to driver safety and distraction. When the driver is given a secondary task (such as learning), the focus from the primary task (driving) gets distracted, and hence that could cause a mishap [130] [131]. On the other hand, when deploying a minimal gaming interface, such as the ones in existing architecture [101] [102] and [117], the user involvement decreases over the period of time because the interface remains passive (certain elements of passive gaming are observing, listening, etc.) for the users. If we make games more reactive and induce active gameplay then again it might lead to distraction.

Having this consideration, I introduce the first research question, which is:

RQ1: How can we design a game logic to foster games for improving mobility quality?

The existing warning systems or driver assistance systems [68] [69] [70] [71] and [72], focus more on intimating the drivers regarding the flaws and alerts. When it comes to improving a driver behavior, the alerts and other intimations can warn the driver but will they impact the driving performance on longer run? Therefore, the second research question is:

RQ2: How can we attain behavioral impact and improve driver performance?

While deploying a game, it should be targeted for long-term use as the user needs to be motivated to progress and adapt the gameplay. The negative perception may demote the users to continue with the gameplay [132], and when the user motivation reduces the accomplishment of major goal might fail. Especially in user-centered models, the necessary involvement of user needs to be monitored, and the systems need to evolve based on the user preferences. Even though the fundamental ability of games focuses on user involvement and motivation [133], the process of making users progress with the gameplay constantly is a challenging factor.

As stated by [113], the attempt to draw player's attention in games has led to attention drop on roadside environments, which is crucial for games in mobility. The gameplay must motivate users and also constantly keep them on track to achieve better efficiency.

RQ3: How can we motivate the users in gameplay?

The use of games in the transportation sector is a budding research area, and several projects are carried out in this domain [105] [106]. However, the process of implementation comes with various questions concerning the ease of use, safety, and motivation. Therefore it is a user-centered process, which aims to improve the driving behavior. It is necessary to understand the game design parameters, user preferences, and deployment analysis; then only a solid framework can be determined for creating better user experience.

The ultimate research question (RQ4) will target the user acceptance:

RQ4: What would be the user acceptance in games for mobility?

The metrics for user acceptance should focus on the user satisfaction, user willingness and assets of game elements. Having all these considerations, my research activity was focused to address the key research questions and to model a framework of serious games to support green and safe driving. The outcomes from user acceptance study and game design metrics have supported to form a collaborative gaming functionality in the serious games application. At first place to address the RQ1, the games in SG_CB architecture was targeted to provide real-time feedback to the users based on their driving performance. The real-time feedback assists the drivers, while on travel to get the immediate updates of their performance and this can further highlight the drawbacks of harsh driving performance in games. While designing the feedback system, careful consideration was taken to avoid distraction from driving task by implementing an audio feedback module and non-interactive gaming interface. The user gets an update about the game status on a timely basis without needing to look the smartphone interface. A collaborative gameplay mechanism was deployed to encourage more users to participate in the game and also for information sharing. The inputs for the games are derived from real-world driver performance, so the game environment is attached to the user inputs from the physical world.

The performance outcomes (either harsh or optimal behavior) gets reflected on the game scene with effective feedback to keep the users updated about individual and comparative performances. The whole idea of the serious game application is to form a virtuous cycle to impact the driver performance by altering the user choices in the real-world. Another aspect of the system design was to make the architecture more scalable to adopt the new applications as well, through this mechanism the entire architecture supports the "plug and play" methodology, where new games can be plugged in based on user preferences. The system architecture is a cloud-based framework, and all the user details and game information get stored in the cloud. Through the scalable architecture, even new applications can be introduced to existing games, for example, let's consider that an application is dedicated to track how efficiently the users are managing parking slots. In this circumstance, the user inputs can be sent to the games and based on their parking management the performance in games might vary.

The centralized cloud architecture supports the ease-of-use, where the users can check the entire details and analytics of the game while on the travel. The RQ2 emphasizes more on the behavioral impacts and this concern is a major aspect of this application. The game design and architecture will have a separate focus on driver coaching module, which will improve the causal understanding of the users based on the exhibited events during the drive. A detailed review and visualizations will be provided to spotlight the harsh driving maneuvers, so users can correlate their outcomes of driving with the gameplay.

The RQ3 focuses on the user motivation, and it depends more on the game design, HMI, and feedback. The real-world incentives are attached as rewards for accomplishment in the gameplay; the user gets monetary benefits for better performances. The strategies involved in the gameplay comprises diversified game logic to cater various types of users, and the game typologies include comparative gameplay, personalized feedback system, collaborative gameplay, and performance visualizations. Additionally, a basic social networking system has been setup for users to participate in groups and to share useful information about the on-road happenings. The RQ4 deals with user acceptance in games, and it is necessary to analyze the usability tests to derive a conclusion for the influence of games in automotive and transportation sectors. The field test and usability study were conducted at various test sites in Europe, and the key aspects of the tests were centered on the user acceptance and willingness to use. The data regarding the gameplay mechanisms and user preferences were extracted for modifying the system components and this data can be used for future game design and development process in the automotive industry. Thus, the research questions were directed to address the pitfalls in the existing systems, and the research outcomes were centric on bridging the gap between the user participation in games and improvement of driver performance.

3.1. Research Methods:

Considering the specifications set by the hypothesis, the research methods involve development of games, field tests and comparative study, in two aspects. For the final analysis the comparative study was conducted on two aspects with the former one focusing on the comparative study between the test results conducted in two test sites and the latter one focusing on the pre and post-test analysis. The comparative analysis will reason the game typologies, field tests and user acceptance in games. Additionally, the analysis will be an opportunity to discover the assets and demerits of each game. The quantitative assessment methods emphasize on the aspects of usefulness and affective satisfaction, where on both the cases a pre and post test analysis were conducted. The pre-test analysis provides the user expectation criteria of the games and the post-test analysis will investigate upon the user acceptance and satisfaction ratios.

As, the driver and passenger games were developed during the later stages of research, it was a good opportunity to validate the efficiency of both the games with previously developed ones (competitions, virtual bank and Snakes and ladders). The detailed description of the analysis is provided in Chapter 7: Experimental results and analysis.

TEAM Collaborative EU FP7 Project

The TEAM (Tomorrow's Elastic Adaptive Mobility) is a collaborative EU project, the project aims at exploiting the mobile devices (smartphones, tablets, etc.) to improvise the transportation safety, securing environmental aspects and the formation of a collaborative network of the road users to reduce the fatalities in EU (see **Figure 5**). By combining the road users (drivers and passengers) and infrastructures, the network gets stronger, and forms a perfect base for the Internet of Things in road safety and optimizes driver performance. The TEAM project comprises various applications focused on driving, parking, and navigation, one amongst those applications is my research domain, which the SG_CB (Serious Games and Community Building) application.

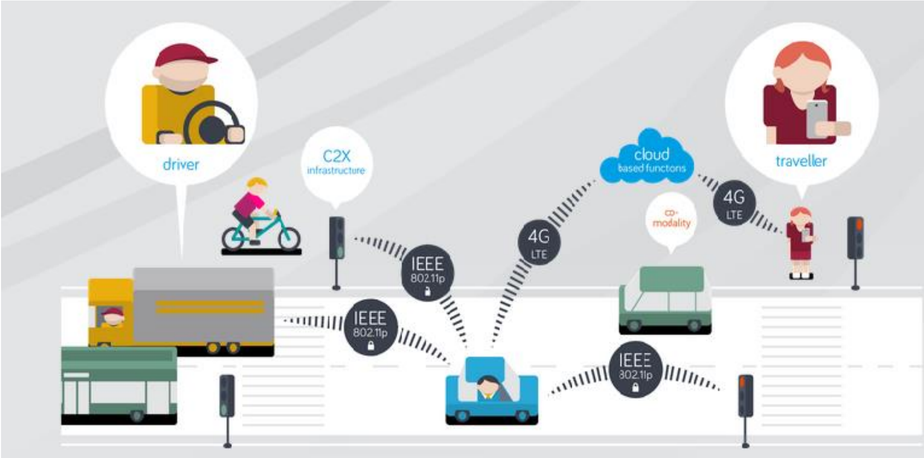


***Figure 5**: Collaborative network of road users through cloud-based function*

The SG_CB application is part of the application cluster that is aimed to improve end-user behavior regarding better driving. The game infrastructure of the SG_CB application was utilized by other TEAM applications such as EFP, CONAV, CPTO, and SD to motivate the user choices and influence user behavior in the aspects of navigation and parking. The project TEAM comprised of various field and plug-in tests in 5 European test sites: Italy - (Turin and Trento), Germany - (Berlin), Sweden - (Gothenburg), Greece – (Trikala), and Finland – (Tampere).

TEAM applications Plug-in test

The plug-in test for TEAM applications happened in Gothenburg, Sweden from January to March on three sessions. I participated in the first test session, which was conducted on 27 - 28 January 2016. The serious games application was tested in ASTA (All Service Test Area) Zero test track. The acquired results helped in evaluating the developed system and also in refining the bugs. The results from the field tests were also published in two conferences (ApplePies - 2016 and GE Annual meeting - 2016). For this plug-in test I contributed the Event-Analysis module, basic Social Networking and Competitions design.

TEAM Euro EcoChallenge

The Euro EcoChallenge was conducted at Italian test site in CRF (Centro Ricerche FIAT), Turin on 15 - 19 February 2016. The various TEAM applications were tested during this event along with user studies. I participated in this event and coordinated with research team in CRF. The Eco-Friendly parking application (developed by CRF) exploits the game logic from the serious gaming architecture, so we performed certain tests to ensure the seamless functioning of modules. The test drive with varying driver behaviors (harsh and smooth) were also performed for the analysis of the impact on the games.

The serious game architecture had been tested at various test sites in Europe and in which, I participated in demonstrations in Turin and Gothenburg. The demonstrations and interactions which I had with test users and other collaborators in this project gave more scope for tuning the system towards betterment. The results extracted from the tests were used in the publications and other project deliverables. The project was concluded with a final meet in Berlin, Germany on October 18 - 19, 2016, with a live demonstration of the serious games application. A video of the functionality was captured with a test session in Genova comprising driving performances of two users (see Demonstration and video links).

My contributions and research activities in Serious Gaming Framework

As, this research activity was associated with a collaborative EU project, I have specific roles associated with the development and the activities that are carried out by me are as follows:

The ground work and analysis were started in November 2014, the preliminary task was to select an algorithm that would capture the driver behavior at good pace. The development activity associated with vehicle signal processing was started in December 2014, where the vehicle signals of test drive were collected for processing. The initial step was to process the signals and bring the raw signal data to the OSGi environment. I developed the evaluator application and in Java and deployed it in OSGi platform, the study on OSGi environment including the methods of deploying bundles, wrapping JAR files as bundles and conversion of external libraries into bundles were studied. Using all these techniques the signal values were transmitted from the test log files to standard OSGi environment. Post this, the second stage of development started with implementation of algorithms for evaluating the driver behavior.

I worked on supervised learning algorithms for classifying the harsh and smooth events, where I used Naive-Bayes classifier to split the events. This algorithm provided an optimal accuracy and much improvised performance. Then Naive Bayes classifier was further extended to track the conflict of vehicle signals by providing certain samples in the frequency table of the supervised set. Simultaneously, the results of the evaluation and certain outcomes were displayed on an Android application (Example: user scores, rewards, etc.). After all this evaluation, I planned to insert a module which would provide coaching for the drivers by displaying the georeferenced driving events (harsh brake, high RPM levels, low acceleration and etc.) on Google maps. I worked on Android development module in displaying the data on Google maps and finally integrated the driver coaching module ("Event Analysis") to existing android application (previously built structure to display evaluation results and user rewards). Another significant approach in this project was to create an interlinked network of road users, passengers and vehicle information stations for visualization and collaborative information sharing network.

This entire control flow of collaborative network of users were also displayed on Google maps in the android application, which I developed. Basically, it's collaborative map, where the users can check the posts from nearby users and can share information about the on-road happenings and this data was used in basic social networking section as well. I contributed for the complete UI design of the SG_CB smartphone application, competitions menu and also for the Snakes & Ladders game logic during the initial phase of research. After the first plug-in test I focused more towards the instantaneous feedback module and on the process of it, I developed the driver and passenger games. I designed the game logic and complete gameplay mechanism for both the games. The passenger game was developed outside the SG_CB smartphone application, so I worked on with the Cocosharp 2D gaming platform to develop the game interface for the passenger game. Later I synced the data from SG_CB smartphone application into the Passenger Game for visualizing the impacts. Finally, I conducted the user tests in Genoa and managed various driving sessions with multiple users.

Chapter 4: System architecture and components

The fundamental concept of the SG_CB application is to create a virtuous cycle to improve the user behavior in mobility standards considering the various aspects such as types of users, vehicles, applications and the context of usage.

On a circumstance where more number of users and applications are involved the primary aim of the SG_CB application was to support a variety of applications for improving the user performance. The social gaming typologies comprise five different games focusing on competitive grading, event-based game, and reality – enhanced gaming. Predominantly the SG_CB application was developed to assess the driver behavior and to provide the gamification/feedback for the driver performance.

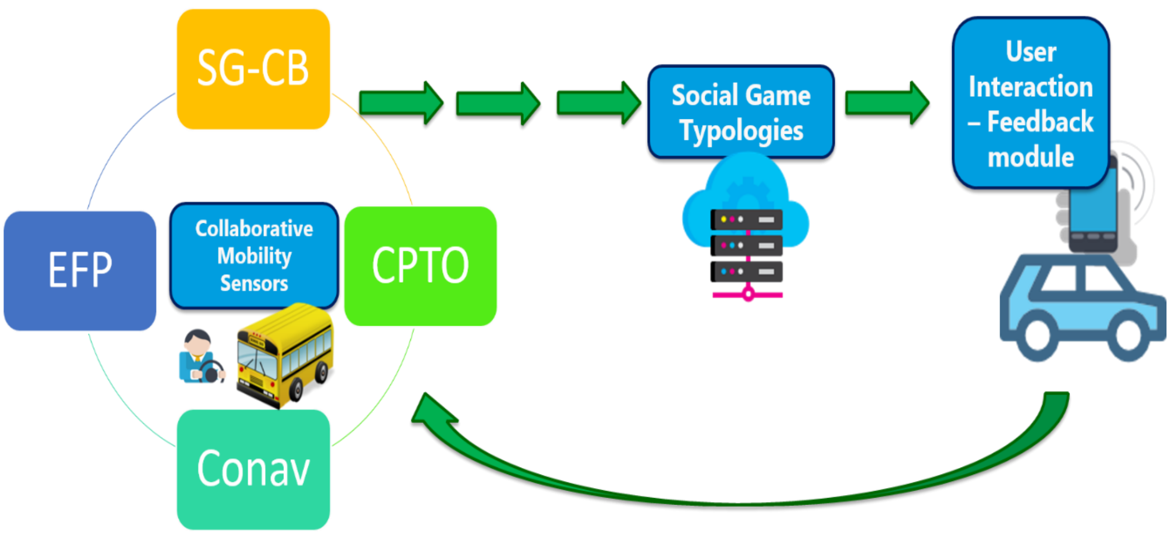


Figure 6: *Architecture for gamification process and the concept of virtuous cycle to improve user behavior*

The concept of serious games can be exploited to promote better user performances in multiple contexts apart from driver performance assessment (such as parking and navigation applications), so even the external applications can utilize the game services (social game typologies) to motivate users in making better choices. The centralized cloud architecture comprises the management and processing of user performance details (performance and analytics) for the social game typologies.

The cloud server manages the game functionality and user performance tabulations; the reference architecture of the system is a service-oriented architecture [134] [135] [136].

Table 1: *Outline of TEAM applications and Virtual Sensors used with the serious game*

Application/VS	Developer	Description	User performance assessment metrics
Collaborative navigation (CONAV)	Fokus Fraunhofer (Germany)	The application provides navigation according to criteria suitable for large groups of people. Especially manages the traffic load by calculating aligned, personalized routing.	User's fulfillment of the provided route indications (event assessment)
Eco-Friendly parking (EFP)	CRF-FCA - Fiat Research Centre (Italy)	Help drivers in finding parking slots and monitors of how well they are managing the parking slot.	Notification of leaving/taking parking. Notification of departure time. Fulfillment of the declared departure time (event assessment)
Collaborative Public Transport Optimization (CPTO)	ICCS (Greece)	Dynamically adapts the public transport bus service according to the actual user demand	Fulfilment of the declared time and itinerary requests (event assessment)
Green drive (GD)	University of Genoa (Italy)	Evaluation of green drive performance	Driver performance evaluated through processing of CAN signals and of smartphone signals (periodic and event assessment)
Safe drive (SD)	VTT (Finland)	Evaluation of safe drive performance	Driver performance evaluated through processing of GPS signals (periodic and event assessment)

Therefore, the entire process can be broken down into three steps:

- The applications, which assess user performance acts as a virtual sensor (VS) and this virtual sensor extracts the real-world user performance and sends it as an input to the social game typologies (which are typically housed in the cloud server).
- The social game typologies process the user performance data extracted from the virtual sensors in the cloud server, and the outcomes are sent to the SG_CB smartphone application (through RESTful web services).
- The smartphone application is the end-user interaction, where the user visualizes the outcome of performance as games, analytics, and reports.

Henceforth, the application forms a virtuous cycle in reflecting the real-world performance of users and based on feedback the user alters the real-world performance in driving, parking and navigation applications. The two assessment modes performed by the VS are based on the events and scores, the former one focusing on the good/bad events exhibited by the user and the latter one focusing on the continuous assessment (usually a score ranging from 0 - 100). For example, the Eco-Friendly parking application (EFP), notifies an event if the user has managed the parking slot well in the allocated time.

The list of sensors that are used in SG_CB game typologies are listed in the **Table 1**, the applications CONAV, EFP, CPTO, and SD were the external sensors, and the application GD was developed by our research team to estimate the driver performance. The GD sensor has two evaluators:

- ***Instantaneous evaluator*** - an in-car evaluator, which assess the vehicular signals (such as acceleration, speed, engine RPM and brake) and provide scores based on it. The vehicle signals such acceleration, brake, engine RPM and speed are extracted through CAN bus and sent to the driver performance evaluators housed in-car for processing. Based on the evaluation criterion the users are provided scores for the performance. Evaluation algorithms [143] perform the analysis and specifically for tracking events, the ad-hoc algorithms were developed to penalize the harsh maneuvers.

- ***Smartphone-based evaluator*** - utilizes the in-built functionalities of a smartphone such as GPS (Global Positioning System), accelerometer and gyroscope and provides the result by associating them with the performance of the driver.

The user just needs to mount the smartphone on the dashboard of the car, and then the evaluator extracts the signals from smartphone sensors (as discussed before) and evaluates the performance of the user. Periodically, the scores are transmitted to the cloud server.

Both these evaluators run simultaneously in-car and evaluate the driver performance on two distinct metrics, and the evaluation results (the scores ranging from 0-100) are then transmitted to the cloud server for further processing. The evaluation scores computed from these two evaluators are forwarded to the game typologies (see **Table 2**). Each user has a separate account in which they can manage their gaming activities, and the entire workflow is displayed on a smartphone with detailed representation of scores, virtual bank, and events.

Table 2: *Game Typologies in SG_CB application*

Game Logic	Strategy/Mechanism	Resource	Outcome
Competitions	Comparative analysis	User performance assessment scores	Rankings, charts, and hall of fame (comparison with friends)
Driver Game	Instantaneous feedback	Instantaneous evaluation scores	Audio feedback and performance evolution
Passenger Game	Arcade space shooter	Instantaneous evaluation scores/ energy factor	Typical game scene where player combats the enemies
Virtual bank	Incentives store	Achievements in games	Transactions of virtual coins gained from various applications
Snake and Ladders	Virtual performance evolution	Optimal events	Visualize the player position on virtual S&L board along with position of peers

4.1. Impact of games on the driver performance

The social game typologies intend to impact the driver performance through HMI, and the user can analyze the performance outcomes after the trip/real-time feedback (performance gamification, bonus and malus gauge, and evolution of performance on the event-based game). Every drive of the user will have something to convey as a part of betterment and eventually, contributes to eradicating the harsh driving behavior. Under the hood, these game approaches convey a mode of feedback to the drivers in the form of incentives, scores, audio feedback and performance visualization. The feedback from the game approaches takes a combinational effect on the user performance by inducing the knowledge and comprehensive understanding of the driving behavior engagingly. The goal of the user becomes to gather incentives, and on the pursuit of it, there will be a competitive platform for enhancing the driving performance. The major impact of these game approaches on driver performance would be an emphasis on two attributes, which are the rewards and downfall. The rewards will act as a factor of motivation to improvise the driving behavior and to maintain the optimal performance to earn incentives. Whereas, the downfall in scores and performance would provide an extensive analysis of performance, which enables the users to understand and react towards eradicating the bad driving behavior. In this section I will address the research questions RQ1 and RQ2 concerning the design and behavioral impact aspects.

The current implementation of the system was done in Java using JPA2 to interface a MySQL database. The interface is provided by RESTful web services hosted by an Apache Tomcat application server. The real-time games (Driver and passenger game) were developed on an Android platform through Cocosharp 2D game engine, Xamarin. My research activity involved the design and development of the social game typologies, event analysis and basic social networking. The suite of games (competitions, virtual bank, event-based game, driver game and passenger game) are targeted to manage different mobility contexts, user needs, and requirements.

4.2. Control flow and social game typologies

The description of the control flow from virtual sensors to end-user interaction is displayed on the below figure. For more specified description, I have focused on the GD application, which was dedicated for driver performance assessment and gaming. The various game typologies are also discussed below in detail (see **Figure 7**).

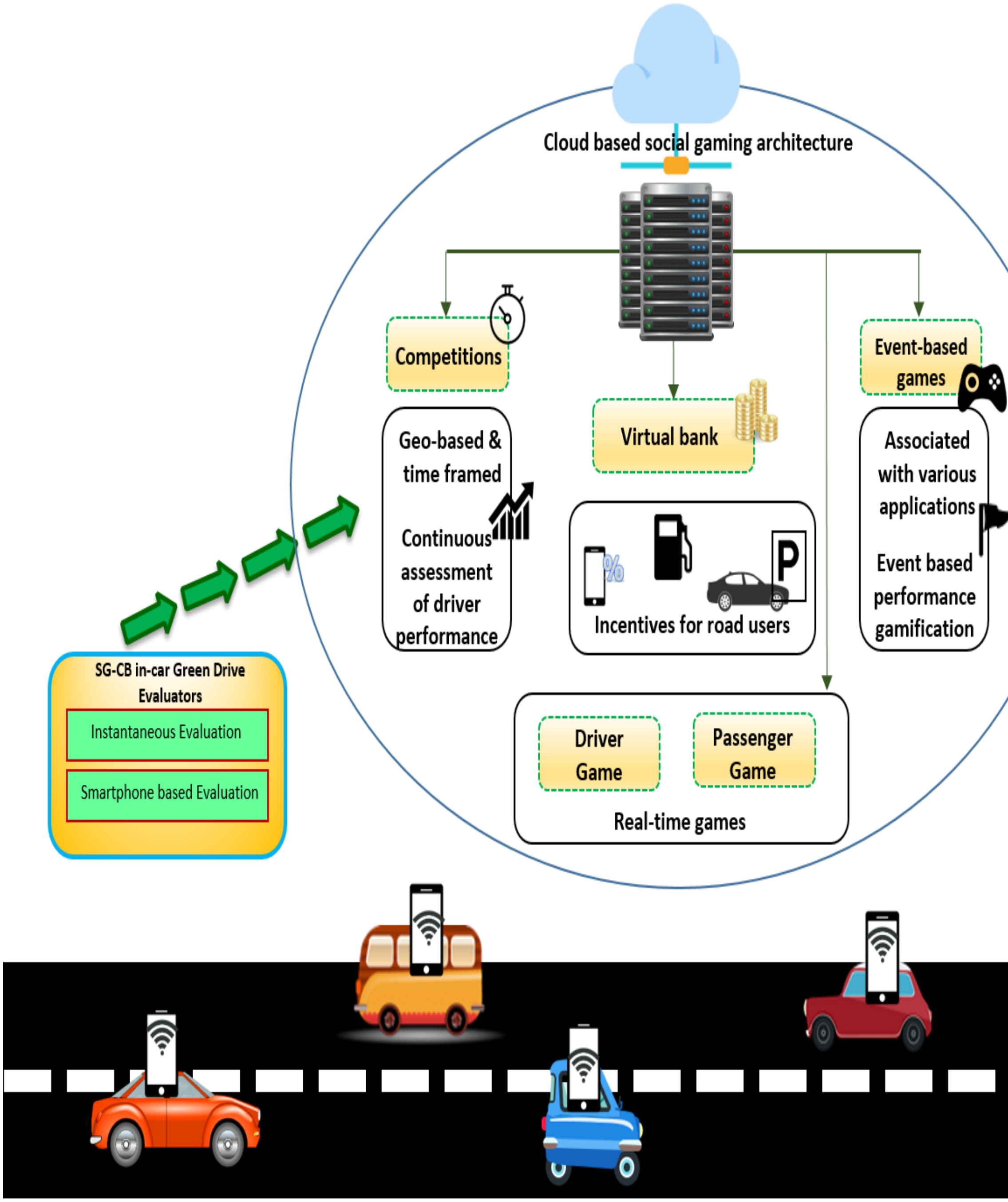


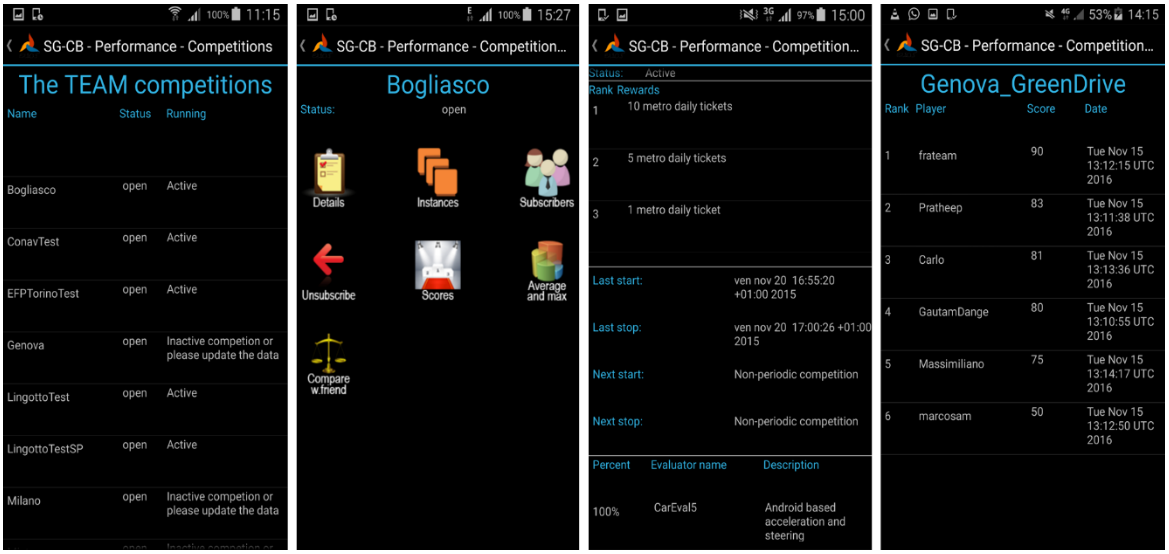
Figure 7: *Control flow of system architecture and components associated with SG_CB application*

4.2.1. Competitions

In competitions approach, the users can take part in a time framed competition (a competition might last from 10 – 15 minutes depending on the locality) by subscribing to the open competitions (the competitions are opened on a timely basis) and exhibit better driving behavior to surpass the peers in competition. The term competition on this occasion can be defined as a geographical location associated with any road network in a city. In a competition, users are evaluated for their performance by the two green drive evaluators on the basis of vehicle signals (acceleration, brake, engine RPM, and speed) and the smartphone signals (GPS, accelerometer, and gyroscope). Once the user subscribes a competition, then the performance evaluation gets initiated, and the scores are transmitted from the evaluator module to the cloud server for every 2 minutes. The proportion of 2 minutes for the evaluation time frame corresponds to the time window to capture the driving behavior for a particular time limit and by various tests, the time frame of 2 minutes was determined as optimal evaluation interval. Once the scores get piled up in the cloud server, the average performance is computed from all the samples, and it is displayed on the smartphone application. The users can check the details, when they wait in traffic or when they have completed the trip.

Each competition has separate rewards and time limits; these time limits can be customized based on the user requirements. But for the tests, the privileges were given to the moderator, where the moderator creates a competition and users can only participate, and they cannot modify the competition settings. On real-time deployment, the users can be given this privilege to setup competition, rewards, timeframe, and milestones. The SG_CB smartphone application comprises a competition tab, and the users can access it through their user profile. While on travel, the users can check the scores of their subscribed competitions and also can look for the fluctuations in scores based on the performance in competition (see **Figure 8**). On completion of the competition, users can check their detailed report of scores, rankings, performances, and comparison with peers. The competition strategy, grant scores and generate the rankings based on the comparison of user performance with the performance of peers, so this aspect comprises an impact in evaluation from various users in the competition. Some virtual coins (depends based on moderator settings – for example: the user can get 100 virtual coins ,if he wins a competition) are also granted for scores secured in the competitions. Whilst, analyzing the performance in competition, the users are also assessed on harsh driving events such as harsh braking, high acceleration and high levels of engine RPM.

At the end of the competition, the tracked harsh events are displayed on Google maps along with the harshness level (high or average) and this methodology would serve the purpose of training drivers by making aware of the harsh patterns exhibited during the drive.



(a) (b) (c) (d)

***Figure 8**: Snapshots from the Competition interface, including (a) the list of the available competitions, (b) the competition info menu, (c) the details about a competition, (d) the current competition's ranking*

4.2.2. Virtual bank

The users get incentives through "Virtual Coins, " and these are points, which user acquires as rewards. The virtual coins (rewards granted based on the individual performance) are awarded for optimal driving/better performance. The virtual coins are accumulated in the virtual bank, and they can be used on real-world entities such as purchasing bus tickets, reservation of parking space, etc. Each application grants virtual coins for various aspects, for example, Eco-Friendly Parking (EFP) provides virtual coins if the user manages the parking slot and time loyally by parking the vehicle in the requested time limit. In CPTO application, the virtual coins are provided for better management of travel instructions from the service provider. Virtual coins are granted as result of better events (for example in the SG_CB application, when the user wins a competition then certain amount of virtual coins are awarded).

In SG_CB application, the users can receive a maximum of 100 virtual coins in a day, and this criterion depends on the various applications. The SG_CB smartphone application provides the entire details of virtual coins transactions, list of virtual coins acquired from the various application, virtual coins spent on purchasing real-world apps and graphical representation displaying the weightage of acquired virtual coins from all applications (see **Figure 9**).

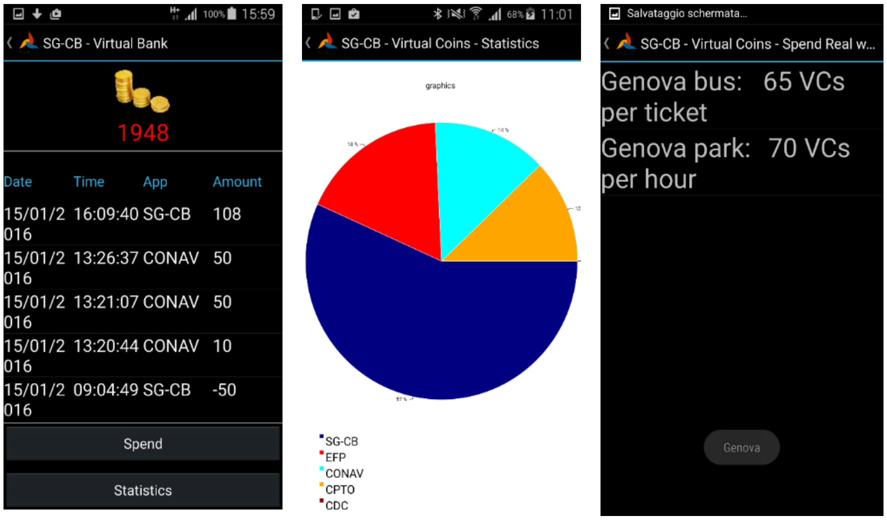


Figure 9: *Virtual Bank snapshot from SG-CB application, (a) virtual bank home with virtual coins balance, (b) graphical representation of virtual coins gained from various TEAM applications, (c) options to spend virtual coins on real-world applications.*

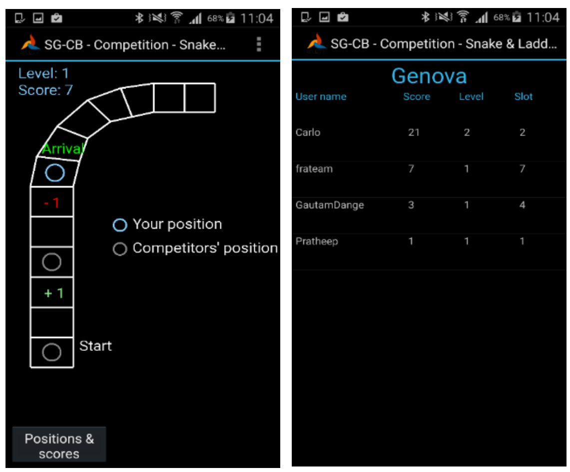
4.2.3. Event-based game

The snake and ladders(S&L) is an event-based game, and this approach is linked to the virtual coins (rewards for the performance). The entire snake and ladders game scene is manipulated with a slate comprising a set of slots (ladder) for the users to progress based on their performance. When the user acquires virtual coins (as a result of good event or behavior), it is converted to the roll-up numbers in dice, and the dice gets rolled virtually. However, a little bit of randomness is involved in the gameplay to avoid monotonous outcomes. Based on the dice result, the user position is forwarded on the slots. The user climbs the ladder and progresses the levels as a result of the better performance. In the S&L game interface, the users can visualize the position of peers and game status (scores secured, present position, etc.).

The snake and ladders approach provide a gamified environment for users to visualize the evolution of their performance and also to compete with the peers associated with the competition. The snake and ladders game comprises of two levels and the complexity increases as the user progresses.

If a user completes two levels, then a championship and additional points are awarded. As this game is associated with virtual coins, even other applications, such as EFP, CONAV, and CPTO can also use this game to display the user performance evolution and comparative position display with peers.

The S&L game for respective user profiles can be visualized by logging into the SG_CB application and the details such as game scene, championships, open games, game charts, etc., are available for the users (see **Figure 10**).



(a) (b)

Figure 10: *The snake & ladders gaming scene, (a) The game interface representing the position of user and competitors, (b) position and scores of users associated with the game.*

4.2.4 Event Analysis – the driver coaching module

The event analysis is a module used for driver coaching through feedback and analysis of the drive. While in a competition, the users are not only assessed based on scores but also, they are monitored for harsh driving events such as high acceleration, harsh brakes, and high steering wheel angle. The event analysis gets generated after the drive by closing a competition instance. The harsh events are captured along with timestamp and geo-references, then they are sent to the cloud server.

At the end of the drive the user gets an entire analysis of the performance in three formats namely the diary, summary and the map (see **Figure 11**).

- *Diary* – the list wise representation of all the events based on timestamp and level of intensity of the event (red for high and yellow for average)

- *Summary* – comprises of the overall grade for the impact of the individual signal on the scale of green (good), yellow (average) and red (bad).

- *Map* - the representation of all the events on Google maps based on the geo-reference of the captured event.

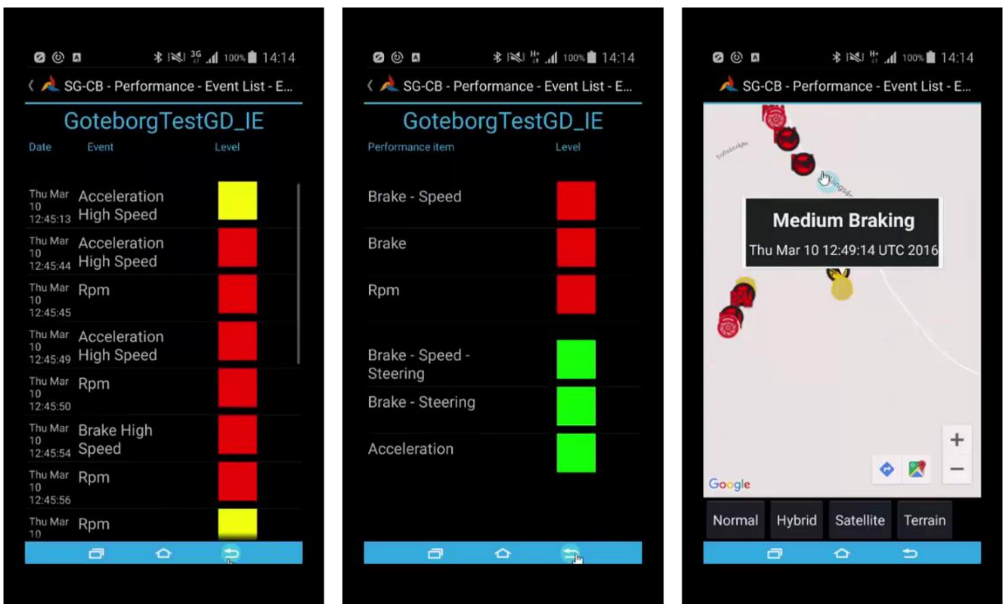


***Figure 11**: Event Analysis option with diary, summary and map views for the test drive captured during the field test in Gothenburg Sweden.*

The visual representation of harsh events along with their intensity will enable the users to determine the current driving performance, and the event analysis can be compared along with competition scores as well. When the scores in competition increases then the number of harsh events decreases and this corresponds to other games as well. In event analysis, the conflict of harsh signals is also represented for more detailed perspective, such as high steering wheel angle with acceleration. Apart from individual harsh events, the combination of two harsh events is a new dimension in analysis, as they display the harshness of the drive with more insights. All the instances of event analysis are stored, and from the SG_CB application, the users can visualize all the event analysis instances to compare their performance and analyze the performance growth. When considering the coaching module, the event analysis option increases the causal understanding of the users to correlate the impacts with the outcomes.

4.2.5. Driver game – A non-interactive gaming interface

The driver game (DG) is a non-interactive gaming option for drivers with features involving immediate feedback of driving performance and a gamified representation of performance evolution. The game comprises two views (driver view and status view) for reducing distraction from driving task (see **Figure 12**). The driver view has gradient window, which initially starts with pale yellow color and eventually shades towards green based on driver performance. This view is the primary game scene, where the internal status, game properties (lives, levels, scores, etc.,) and flow of the game are hidden from the driver, as the more objects and visualizations on game scene tend to create a diversion. Every phase of the game, such as level status, acquiring bonus and pitfalls will be notified to the user (driver) through a vocal interface. Therefore, the user can focus on driving task without needing to look on for game status.

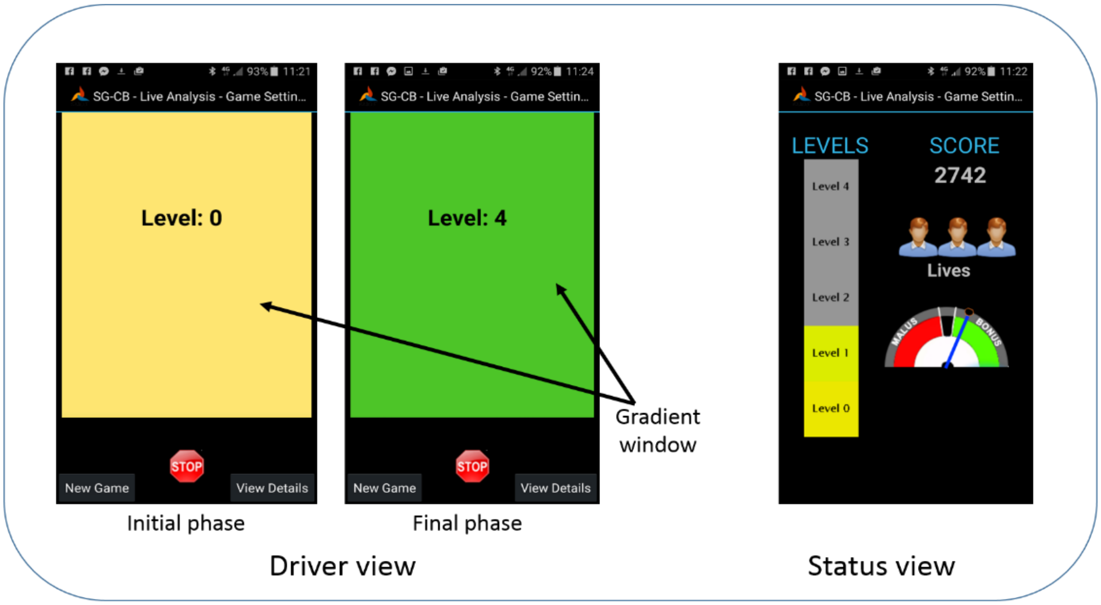


***Figure 12**: Driver game interface – game views (driver view and status view)*

Entire details of game can be visualized in status view and this can be done by a co-passenger or when the driver stops in a traffic. The status view comprises level indications representing the completed levels, scores, bonus/malus gauge for estimating performance outcome based on current performance and lives remaining for game completion. Unlike the driver view, which shades from yellow to green as driver progress the levels, the status view represents the more detailed aspects.

The DG comprises five levels, and each level need to be completed within a certain amount of time (for example: a level can last from 2 - 10 minutes). Initially players are supplied with three lives to complete the game. The task of the drivers is to manage the time and secure better scores, so every level holds a time and target; the player needs to secure average target points corresponding to levels and when the levels increase the target criteria become more and time in which it needs to be secured reduces. When the player completes a level within the specified time, a bonus will be granted for performance, and if the player fails to complete the level, a malus will be incurred with life loss and causes player to replay the level. While replaying a level, the user must show consistent improvement in performance to overcome the loss caused by malus. The malus will not only deplete the player life but also incurs a score drop and this adds up more complexity for the gameplay. The bonus multiplier that gets added up to player scores on completion of a level supports the game progress when the player proceeds to higher levels where the target limits are more. To determine whether the player will secure a bonus/malus based on current performance, a bonus/malus gauge has been deployed, and by comparing the current scores with expected target and time limit, the gauge determines the outcome in current level. The time limit and targets can be customized by drivers as well, and the scores log is maintained in the cloud server. The summary of driver game mechanism can be defined by an energy equation corresponding to the game mechanics associated with driver performance.

$$E_d = (IP_d * LB_l) + BM_l$$

The energy of the driver (E_d) is given by the individual performance of the driver (IP_d) along with level bonus (LB_l) and bonus multiplier of the corresponding level (BM_l). The individual performance of the driver is complimented in each level with a minimum level bonus and the level bonus increases as the user progress with further levels. The bonus multiplier is determined by the user performance in a particular level, if the user completes a level within allocated time the bonus multiplier is added to the final score and if user fails then the bonus multiplier remains at zero.

The bonus multipliers are necessary when the user progresses in the game, because in higher levels the target scores will be more and the duration to achieve them will be less, so in that case the individual performance needs an uplift with bonus multiplier to manage the challenging gameplay.

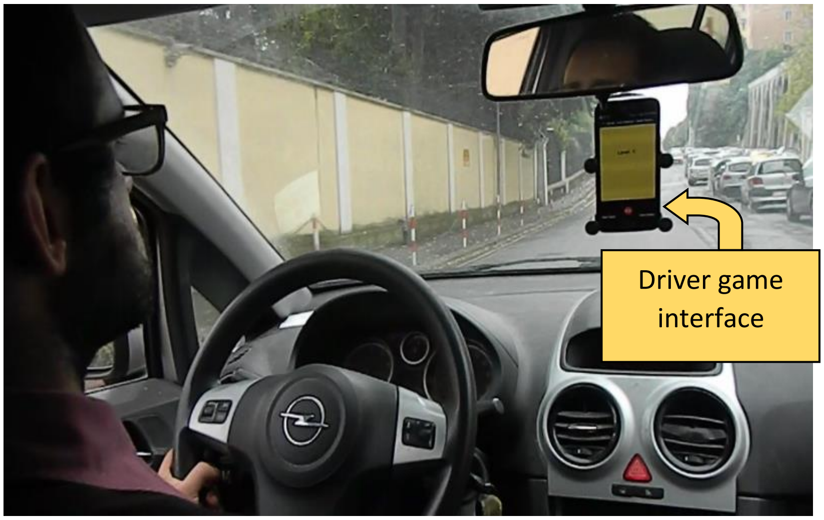


***Figure 13**: Driver game interface installed in-car during field test in Genova*

Game interacts with the cloud server for every 5 seconds to extract the driver performance results (scores ranging from 0 -100, as computed by in-car evaluators) and this aspect facilitates the drivers to understand the immediate feedback of performance on game scene. When the performance is good, there are more possibilities for the player to gain points and progress levels and if there should be a performance drop, then it gets reflected on game scene. The primary aim of DG is to provide a simple interface to support immediate feedback and encourage user participation. The methodology of immediate feedback keeps the user updated about current happenings in the game and ensures that user progresses throughout the gameplay. Thus, the driver game provides a real-time performance feedback on a gamified environment based on driving events such as brake, acceleration, and steering wheel angle (see **Figure 13**).

4.2.6. Passenger game – An interactive arcade gaming interface

The aim of Passenger game (PG) is to extend the gamification process for the community of road users; the driver performance details were exploited to form a source for an interactive gamified environment for passengers (see **Figure 14**). The PG is an arcade space shooter game comprising two levels, and the game is played by the passenger in real-time, based on the driver performance results. The game combines the skills of passenger and context values supplied by driver performance, and the game platform interacts with cloud server for every 20 seconds to fetch the driver performance results (average driver performance scores ranging from 0-100). Passenger game environment adapts the gameplay challenges based on driver performance, as in during better driver performance, the passenger has more scope to tackle the enemies on game scene and progress levels. Whereas, in case of bad driver performance (including harsh maneuvers and braking events), the game scene becomes adverse (entry of multiple enemies on the game scene to form a hindrance for player progress) and more challenging for the passengers. The underlying game attribute comprises of Energy factor (E), and the energy determines the player progress in the game.

$$E_p = IP_p + DP_p$$

The Energy of a passenger (E_p) is given by the Individual performance (IP_p) of the passenger and the driver performance associated with that passenger (DP_p). The energy determines the player progress and if energy is more then the player has more possibilities to sustain the gameplay and if player can withstand the enemies in game play for longer time, then player has more scope to complete the game. The individual performance of the player (such as gameplay skills, combating in game and tackling the enemies) contributes a share for the total energy, because the individual potential is also a concern for the interactive gameplay mechanism. Through IP_p , the skills of the passenger are taken into consideration for the game mechanics. The passenger game comprises a collaborative gameplay and it is associated with the driver performance (DP_p) of the concerned passenger, for example: if the passenger is traveling in a bus(B1), then DP_p corresponds to the driver performance of the bus B1. The DP_p determines the number of enemies that are to be populated on the game scene and when there are more enemies on the game scene, then player gets maximum damage and that can cause the player to lose the game. If the enemies are less, then the player can tackle and combat them with relative effort. So, if DP_p is high (when driver performs well on road with better driving), then the E_p of the passenger increases and when player gets more energy, there are possibilities to refill the health to maximum. Therefore, the energy factor is directly proportional to the player progress in the gameplay.

The process of extracting driver performance results is similar to driver game, but the duration is more in case of passenger game (20 seconds interval), because of the interactive ability, in which passengers can explore the game scene and exhibit skills to manage the gameplay. Through this gamification process, the passengers can have an understanding of driver behavior as it gets reflected on the game scene and also it is an initial step in the extension of gamification elements on the broader scope for road users. As the central part of the game strategy relies on context values of driver performance, the game aspects can be later modified to adapt to any game that might interest users. More types of passenger games can be included in the cloud architecture with different strategies and milestones; the passenger game is one such example of extending the gamification process to passengers. As of my understanding of the existing systems, this game is first of its kind in automotive domain, where a collaborative gaming mechanism with driver performance and player skills are combined in a game interface.

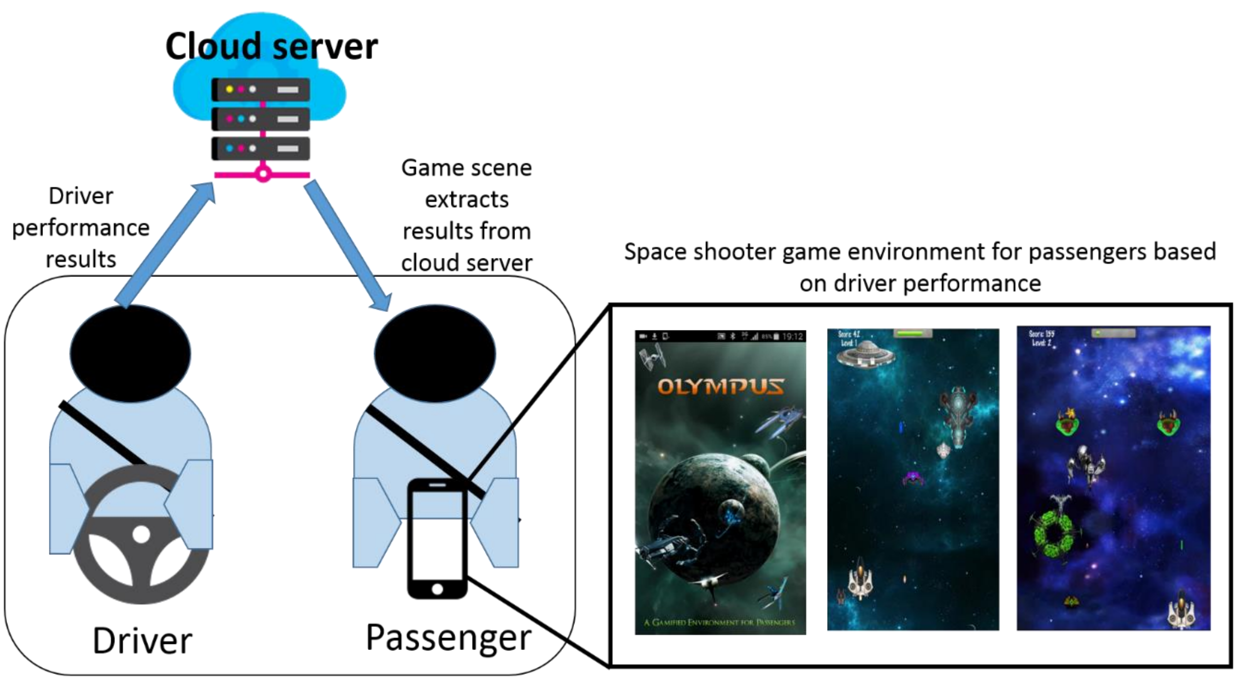


***Figure 14**: The passenger game overview and control flow*

4.2.7. Basic Social networking

The basic social networking option is incorporated into SG_CB smartphone application; the users can check their updates of performance and also can establish their social profile in the community of road users. The social networking option also enables the users to share their performance reports on the wall and in groups. The users can collaborate with their peers regarding information of performances, on-road happenings, and chats. Users can post messages in groups, and these posts are geo-referenced, so other users and peers in the group can visualize the information on maps through – “View close posts” option, where the posts which are nearer to their current location of the user are displayed (see **Figure 15**). The option close posts can be used to understand the updates about the instances happening on a road network, for example: a user can share post, if there is some renovation work happening on a road link, so that other users can be intimated and can change their travel route in order to avoid delays or get stuck in traffic.

Through this social networking option, the users understand about their peers and how their performance stands in the community. The groups can be created and customized by the individual user and the friends can be added to the groups. Users can also check their updates on competition performances, and whenever the user improves performance in competition, they get notified about their betterment.

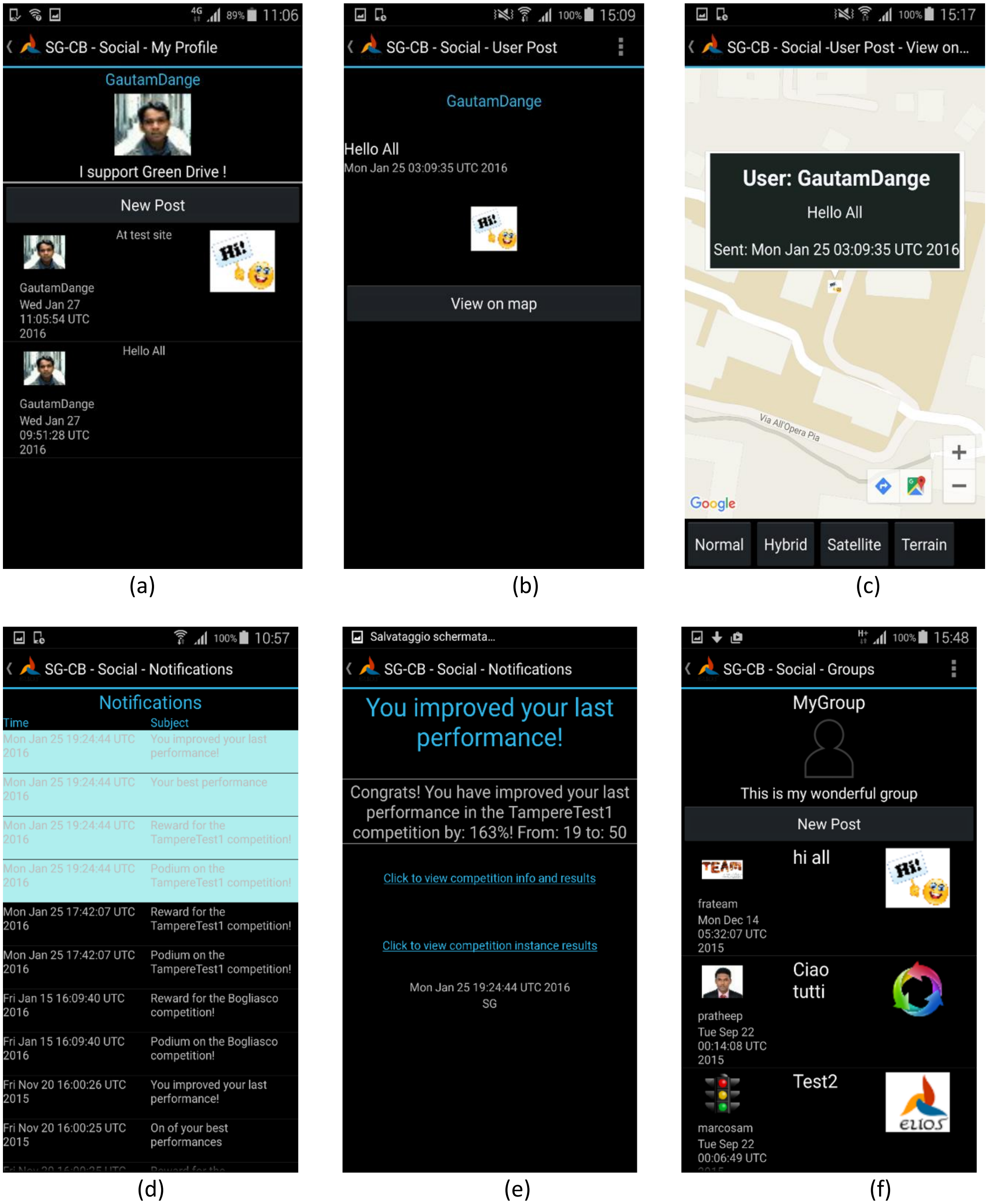


***Figure 15**: The social networking option (a)The user profile and wall for sharing posts (b) posts with timestamps (c) representation of user posts on maps (d) Notifications tab with current improvements in user performance (e) Detailed representation of improvements – achievements in competition (f) Group posts with messages from various users in a particular group.*

4.3. Gaming choices and user preferences

When consolidating the need for the development of these game typologies, the initial analysis comprised of these five game typologies to cater various users but in future more games can be included in the cloud server based on user preferences. The collaborative approach in passenger game facilitates the users to engage in a live interactive game, and the gameplay is the result of real-time happenings associated with user performances. The users who prefer to engage in an interactive gameplay on basis of real-time evaluation during the journey can use passenger game. The DG focuses more on individual performance and immediate feedback analysis with simple gaming interface accompanied by an audio feedback module. The competitions approach provides a comparative gameplay with rankings, scores, performance reports and rewards. Through competition, the users experience a periodic assessment and comparative gameplay along with the peers. Whereas in S&L game, the chances for rolling a dice on better events can display a visual performance evolution through the course of the game. The virtual coins gained by users can be associated with the efficiency in adapting towards the better driving behavior and also for utilizing the benefits from real-world. These gaming aspects can coach and motivate the choices of the users, as the games are a reflection of real-world performances and the users get to understand the implications of low performance. The event analysis module spotlights the harsh driving events in more detailed aspect, where the user can visualize/analyze the impacts of harsh driving maneuvers and how it reflects on the game scene. Thus SG-CB application offers more gaming options for users based on their performance, and the features of gaming application such as incentives, collaboration, comparative analysis and real-time visualization will interest users in adapting towards the safe and green driving behaviors.

Chapter 5: Implementation and deployment of prototype designs

Most of the existing models in serious gaming context for automotive industry aims at improvising driver behavior by various methods. But, there is another viewpoint for this approach (i.e.) out of many methods that could enhance driver behavior, the key methodology would be the representation of qualitative driver performance analysis. The first step in attaining better driver behavior would be devising a qualitative evaluation pattern that would analyze and provide a detailed report (analytics and comparisons) of driver performance. The analysis can be of great assistance in comparing the individual driver performance with the performance of peers. Also the comparative analysis through serious games approach can be used to inculcate the efficient driving behaviors. Having all these considerations as a foundation, the comparative performance assessment schema that would analyze the driver behavior on absolute and social comparison basis was developed.

5.1. Game prototype 1 – Real-time gaming aspect on a simulated road network

In this prototype approach, the initial test was conducted in a lab environment to understand the comparative and qualitative analysis in serious games implementation. The prototype system comprises three major units. The system core manages the driver performance evaluation by unifying three components together (see **Figure 16**), the evaluation is done based on the relative plot of the scores with the average performances of the peers.

The system core comprises of three components:

- Vehicle Simulation Unit
- Aggregation server
- Live User performance enabler

5.1.1. Vehicle Simulation Unit

The vehicle simulation unit acts as the input part, where the signals of 40 vehicles are generated for this entire test scenario. The source of replication is from the real log file, which comprises vehicle signals recorded during the test drive conducted by CRF Trento, Italy. The signal generator unit forms the data structure for the signals that flow in and simulation inventory is comprised of certain configuration files associated with the parallel simulation. The simulation inventory handles the logical signal generation from the real signals and maintains the course of the replicated signals to match with the source signal. The 40 vehicles are associated with 40 users, and the details of 40 users and the signal mapping to concerned users are done in parallel inside the simulation unit.

After signal generation and processing, the simulation unit sends signals to Driver performance evaluator [85] [108]. The driver performance evaluator determines the scores for user performance. The signals such as acceleration, brake, RPM, and speed are evaluated for this simulation tests. The evaluation is done by green drive and fluid traffic metrics, where green drive comprises of the evaluation based on Brake, RPM and acceleration signals of the vehicles and fluid traffic estimate the speed signals. After signal evaluation the driver performance evaluator determines a score for the performance, then the scores and vehicle details of 40 users are forwarded to the Aggregation server (through RESTful web services) for the computation, and only one user score is forwarded to the Live User Performance enabler unit (through Bluetooth module). Later the score of this individual user is compared with the scores of 40 users for deriving the overall performance.

5.1.2. Aggregation Server

The Aggregation server receives the signals of 40 vehicles from the Vehicle simulation unit and stores the entire details of the vehicle signals, geo-references and users associated with it. The key element of Aggregation server is the computation of average performances of 40 users, where the latest and historical user performances are tabulated based on the geographical links. Aggregation server responds to the live user performance enabler module for the comparison of the individual performance of one user with the average performance of all the users that were recorded on the road links.

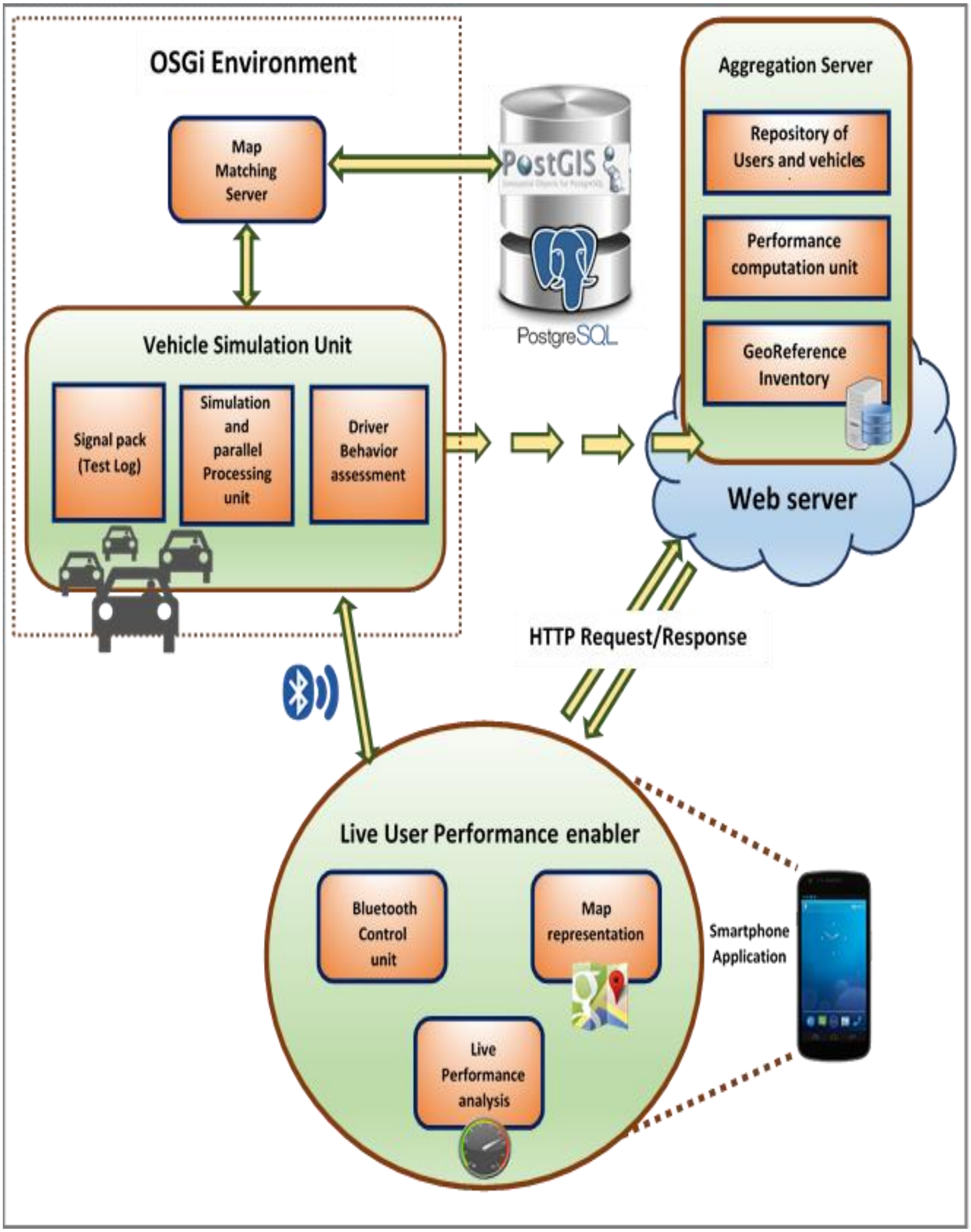


***Figure 16**: Implemented prototype design and control flow mechanism of social comparison module*

Apart from the computation of user performance, the visualization of the performance on road links is another feature associated with this system. In real-world recordings of geo-references, there can be a deviation from the actual position, and this might result in a drastic change when the coordinates are displayed on Google Maps. To resolve the errors associated with variations in Geo-references, a Map-Matching algorithm (The map-matching API “GeoToolBox”) was used to integrate the position data with Spatial Road Network data to identify the correct link and coordinates on which the vehicle is traveling [137]. The vehicle coordinates are sent from the Vehicle simulation unit to the Map-matching module for the correction; the Map-matching module is housed in OSGi framework. The Map-matching module relies on a Geographic database generated from the OpenStreetMap files.

The OpenStreetMap data describing the road network is preprocessed and converted to PostGIS format. Every road is represented by a set of links (Unique identifier), therefore by querying vehicle coordinates, we can retrieve the corresponding road link of the vehicle from the database. Vehicle simulation unit exploits Map-matching module to fetch the entire details of Geo-references and forwards it to the Aggregation server and later these details are used by Live User Performance Enabler unit to plot the road links on Google Maps.

5.1.3. Live User Performance Enabler

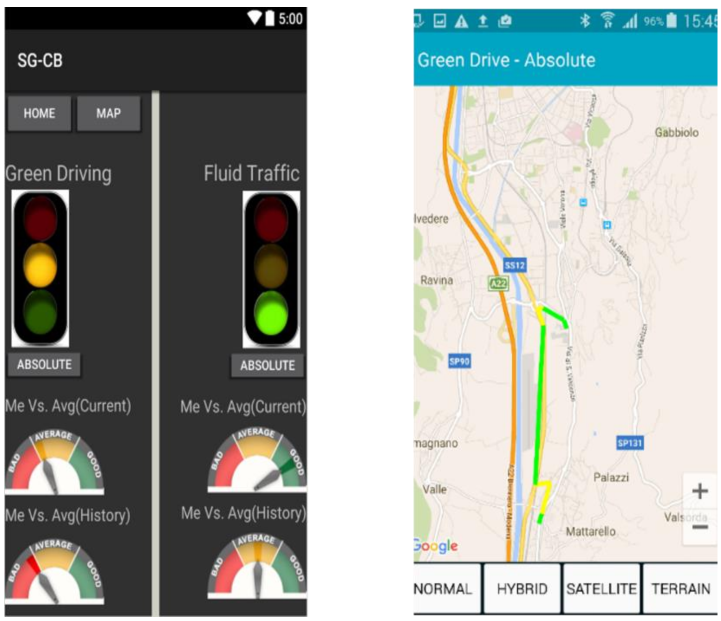
The UI for the visualizations and controls for the simulation game were integrated into the SG-CB smartphone application. The outcome of evaluations is plotted and displayed through various gauges to reflect the individual user performance vs. average performance of all the users on the road link.

The three main functionalities of this block are as follows:

- Communication control
- Performance analysis
- Map based interactive UI

The major activity of performance enabler unit is to communicate with the other two architectures (vehicle Simulation unit and Aggregation server) seamlessly to gather and analyze the data.

The entire architecture is housed into the SG_CB application, and the communication of user performance enabler undergoes two stages. In the first stage, the smartphone application interacts with Vehicle simulation unit using Bluetooth module and extracts the scores of an individual user (absolute score) on the basis of green drive and fluid traffic. In the second stage, the user performance enabler requests the Aggregation server for the latest and historic average values of all the users on the link. The response of the Aggregation server is then compared with the absolute scores secured from the Vehicle simulation unit and are displayed on the gauges with the grading scale of colors (green, red and yellow), where each color corresponds to the driver performance such as good, medium and bad (see **Figure 17**).



(a) (b)

Figure 17*:(a) Live User performance interface with absolute and social comparison gauges, (b) Performance results on Geo-referenced links on Google maps.*

The comparative methodology enables the comparison of user performance with the peers on all aspects of the Green driving and Fluid traffic, apart from the estimation on gauges, the performance measured (respective to various links) are then plotted on Google Maps for further visualization. The primary aim of this test was to ensure the functionality of interconnected modules and entire control flow of driver performance assessment. The implemented interface provides feedback through gauges, but in future implementations, the design aspects need to be considered for better visualizations.

5.2. Game prototype 2- Instantaneous personalized feedback module

Following the real-time gaming aspect of the simulated network, I developed a second prototype, which was an extension of the prototype 1. In Prototype 1, the comparative approach was used to determine the performance quality of individual user, and in prototype 2, the game mechanics involve more personalized aspect - the assessment of driver performance based on an instantaneous feedback module. The game comprises certain levels, lives, score and a predictor gauge. The game interface was developed to create a personalized scoring pattern for individual driver performance. The architecture of the game comprises vehicle simulation unit, which provides the score of one user assuming the performance of particular user on a road link. Smartphone game application interacts with the vehicle simulation unit through Bluetooth module to extract the scores and based on these scores the gameplay changes. The scores act as an input for the game.

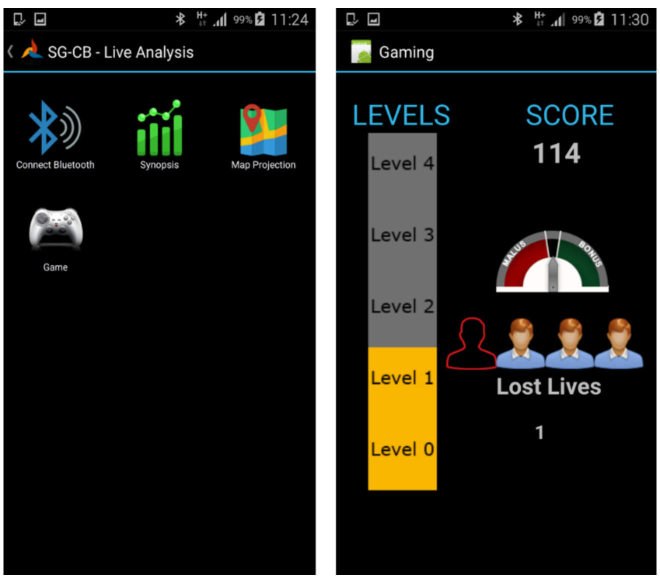


***Figure 18**: Game prototype 2 - Interface design and game elements*

The game consists five levels, and the user needs to clear all the levels, within an allocated time. Each level comprises of a certain time limit to clear, if the user fails to clear the level on the allocated time, then the user gets a Malus and loses a life. Initially, the users are provided with four lives, with which they need to clear all the levels.

The architecture from game prototype 1 was exploited in this implementation with few changes to the control flow. The most of the focus was spent on designing the UI and game mechanics for this instantaneous game (see **Figure 18**).

The game was tested in the simulated environment to ensure the functioning of all the game parameters, such as levels, Bonus/malus gauge, and scores.

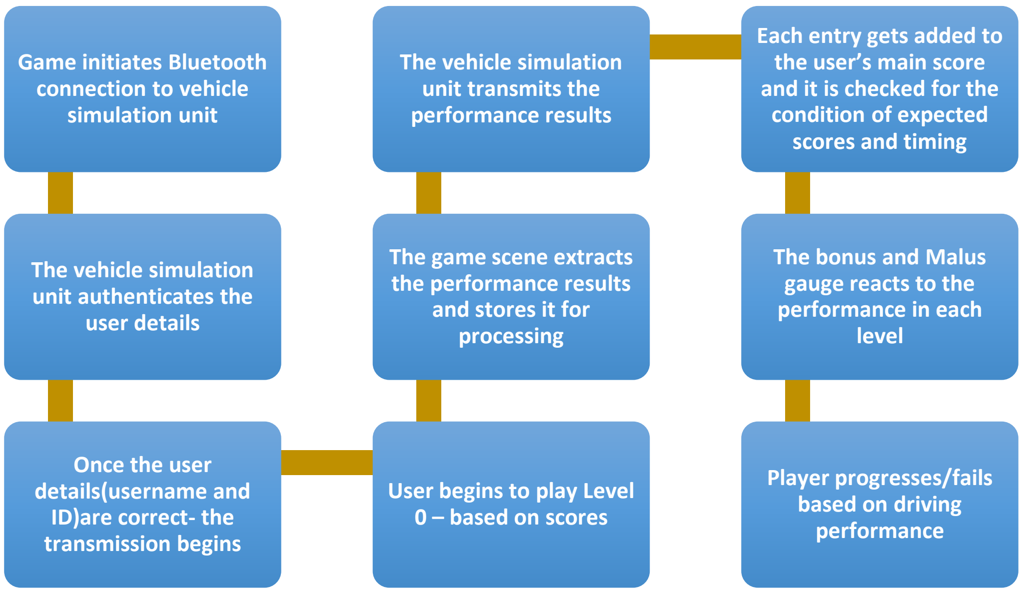


Figure 19*: Test case scenario with steps involved in the gameplay*

5.2.1. Test case scenario

The test case scenario represents the entire control flow of the instantaneous feedback module (see **Figure 19**). When the connection between the smartphone game application and vehicle simulation unit gets established, the vehicle simulation unit authenticates the user details that are sent to the game. This authentication step is necessary, to extract the scores of a particular user. The scores are bounded to the user ID, and thus authentication ensures that the user performance scores are sent to the respective users. Once the authentication is successful, the Bluetooth connection is established, and the game begins with initial evaluation scores from the vehicle simulation unit. The user manages the challenges in gameplay and undergoes the phases of bonus/ Malus depending on the driving performance.

5.3. Game prototype 3 – The Driver game

The driver game was an extension of the game prototype 2 with more alterations in game design and parameters. The game prototype 3 can be segregated into two phases, where the first phase involves few changes in the design (layout and representation) compared to the previous approach and second phase involves the modification in communication medium between the game and evaluator. The user establishes the Bluetooth connection with smartphone-based vehicle signal evaluator to extract the user performance scores and starts the game [138]. This Game prototype was tested on public buses in Genova, where the direct implications of the field tests were analyzed. Some parameters like sensor tuning and gameplay scorings were adjusted during the field tests, and the detailed description of the field test is provided in Chapter 6: Field Tests and Deployment Scenarios. The previous prototype was tested in a simulation environment, but when it comes to real-world testing there are numerous factors that might affect the system such as sensor accuracy, evaluation metrics (for example thresholds for acceleration and brake), gameplay management, adaptation of system to dynamic environment and effective functioning of feedback system(see **Figure 20**).

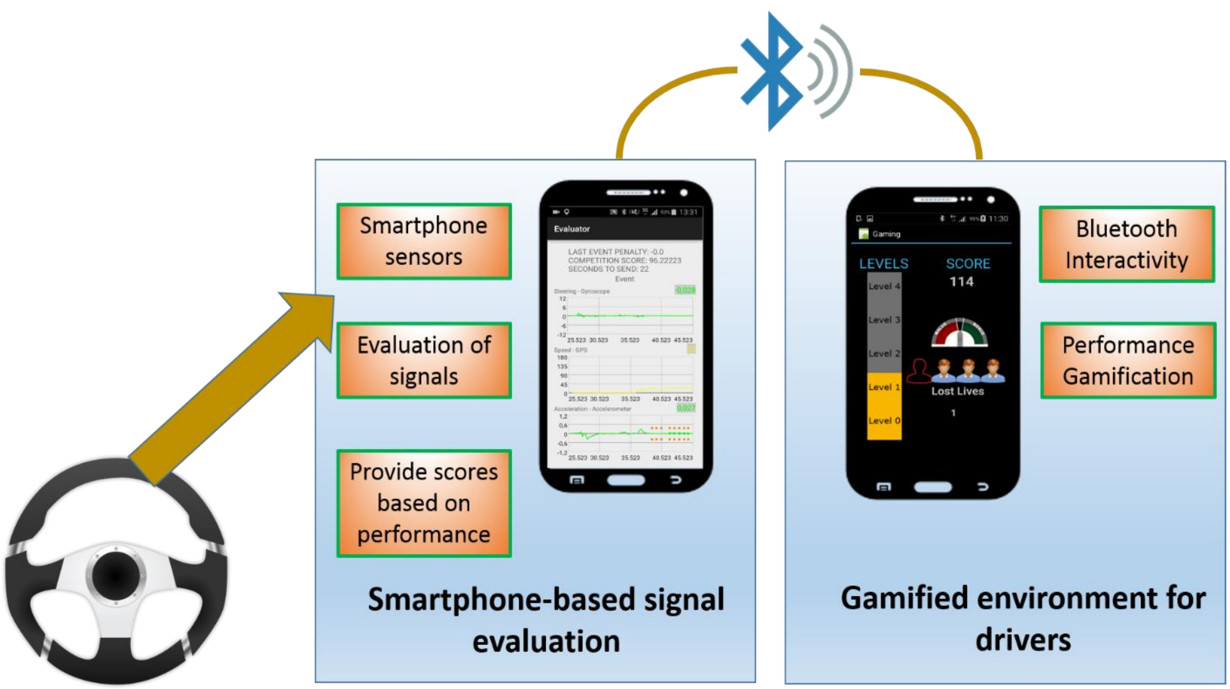


Figure 20: *Initial prototype design of the driver game*

After the initial tests, the driver game application was tested for the deployment study through the pilot test with 10 users. When it comes to deploying in cars, the safety is the key aspect, as it should not create a distraction and influence visual attraction. The smartphone screens were recorded for test purpose, and the updated driver game interface and smartphone signal interface are shared in **Figure 21**.

Figure 21: *Field test snapshots of updated driver game interface*

The first point was to alter the existing design, as it comprises more detailed features of gameplay such as levels, scores, gauge, and lives. The existing design was hidden under a new design comprising a simple driver view with a gradient window shading from pale yellow to green based on the performance. Additionally, a voice feedback was attached to the game, where the user gets a progress update on a timely basis. Through these improvements in design, the user will not have a need to look up the smartphone interface for the details and when the user halts in traffic, the detailed status view can be checked, which is hidden under the driver view (see **Figure 12**). Apart from these changes the Bluetooth module was discarded for simplicity of use and reduction of configurational issues. The updated driver game interface interacts with cloud server through RESTful web services to extract the driver performance results. The updated design and changes regarding the communication protocol were tested again through the field tests in public buses and test drive (in the car). The issues addressed in this prototype enabled to form the better design and gaming aspects of the driver game. The driver game underwent the usability testing with multiple users (see Chapter 7: Experimental results and analysis).

5.4. Game prototype 4 – The Passenger game

After the driver game, the plan was to increase the playfulness and gamification process for more users. The goal was to establish a game for the passengers and to create a collaborative gameplay mechanism based on driver performance and skills of passengers in handling the game. The passenger game is a space shooter game, where the primary goal of the user is to tackle the enemies on the game scene and clear the levels.

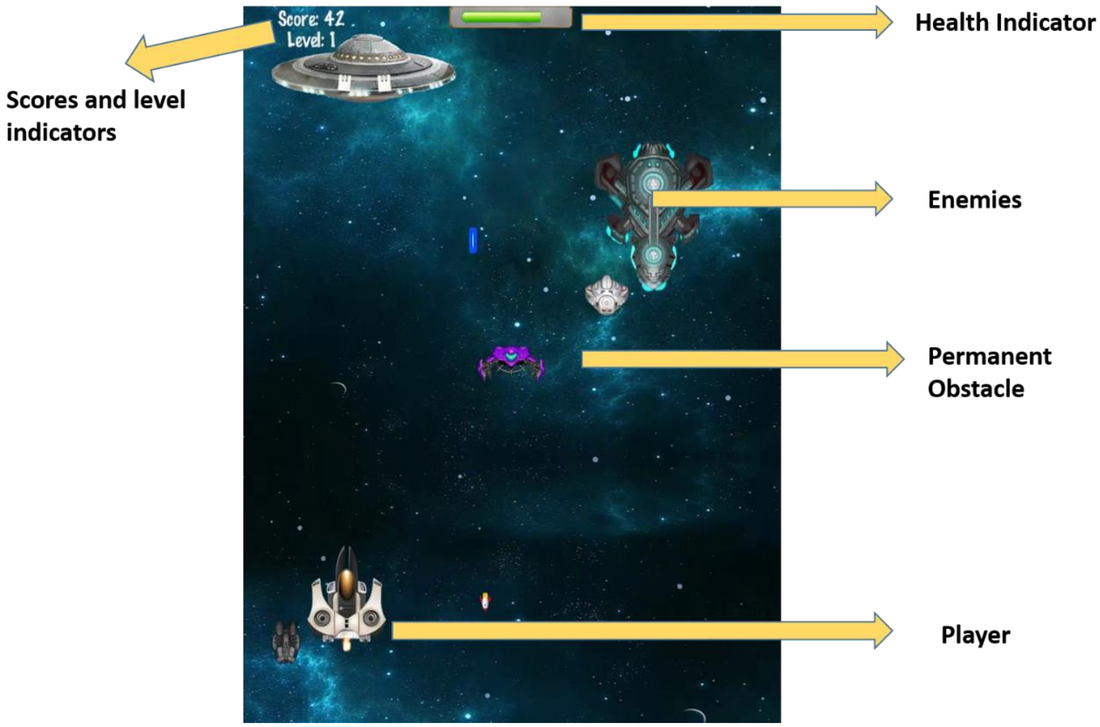


***Figure 22**: Game elements and design aspects of passenger game scene*

The game starts with level-1, and the game scene comprises parameters, such as health gauge, enemies, scores multiplier, health boosters and score indicator (see

Figure 22). Initially the player is supplied with full health and based on the attacks, the player health reduces constantly. The task for the player is to clear each level by acquiring the threshold score, and this threshold score varies based on the levels. The user needs to secure the threshold scores of 100 (level-1) and 150 (level-2) for clearing both levels.

To clear these threshold scores, the health of the player is the key concern, and it depends on the intensity and number of enemies on the game scene. When there are more enemies on game scene, the attack ratio of enemies on the player will be more, so the health of the player drastically reduces.

Additionally, there is a permanent obstacle on game scene, which strikes the player on frequent intervals and this ensures that the player should not remain stationary at a position in the game scene. At various points in the game, the user gets a chance to grab the scores multiplier, which gives an instant boost in scores, but the skills of player determine of how well the scores multiplier can be grabbed by escaping from enemies' attack. Therefore, the number of enemies on game scene and the player's skill determines the success in this game. As the passenger game is connected to the driver performance, the number of enemies is associated with driver performance. When the driver performance is bad, then there will be more enemies populated on the game scene (corresponding to the energy equation discussed in Chapter 4 under the topic 4.2.6. Passenger game – An interactive arcade gaming interface), and this increases the complexity for the player to progress the levels. In turn when driver performance is good, the player gets a chance to acquire health booster, and this can restore the damaged health factor of the player. If a player is fully charged with health, then there will be more possibility for the player to excel the gameplay. Each level comprises of default complexity, such as the permanent obstacle (n=1 for level-1), which constantly remains on the game scene and strikes the player. In level -2, there will be more permanent obstacles (n=2), and they can further damage the player's health. Therefore, it is necessary that player dodges the enemy attacks and manages to withstand the health throughout the gameplay.

The preliminary tests for the passenger game were conducted in public buses in Genova, and a separate usability study was conducted for this game (see sections: Chapter 6: Field Tests and Deployment Scenarios and Chapter 7: Experimental results and analysis). The game obtains the user performance results from the cloud server, and this happens in the extraction time frame of 20 seconds. The tests were conducted on various extraction time frames such as 10 seconds and 30 seconds as well. But, 10 seconds seemed to be much short duration to observe the driver performance in detail and 30 seconds seemed to be more time gap for the passengers to get along with the game scene. So, the 20 seconds time frame to represent results was the ideal point, and however, the user has to manage other difficulties in-game scene as well. The driver performance determines whether to add more complexity or to favor the player by providing health booster.

5.5. Game Prototype 5 – Integration of SG_CB with CPTO module

The virtual sensors allow 3rd party applications to utilize the gaming services offered by the SG_CB application. To test the gaming functionality for improving user behavior, the public transport optimization system developed by ICCS, Greece was integrated with SG_CB module. The CPTO application acts as collaborative mobility sensor for serious game application and provides input for gamification process as depicted in **Figure 23**.

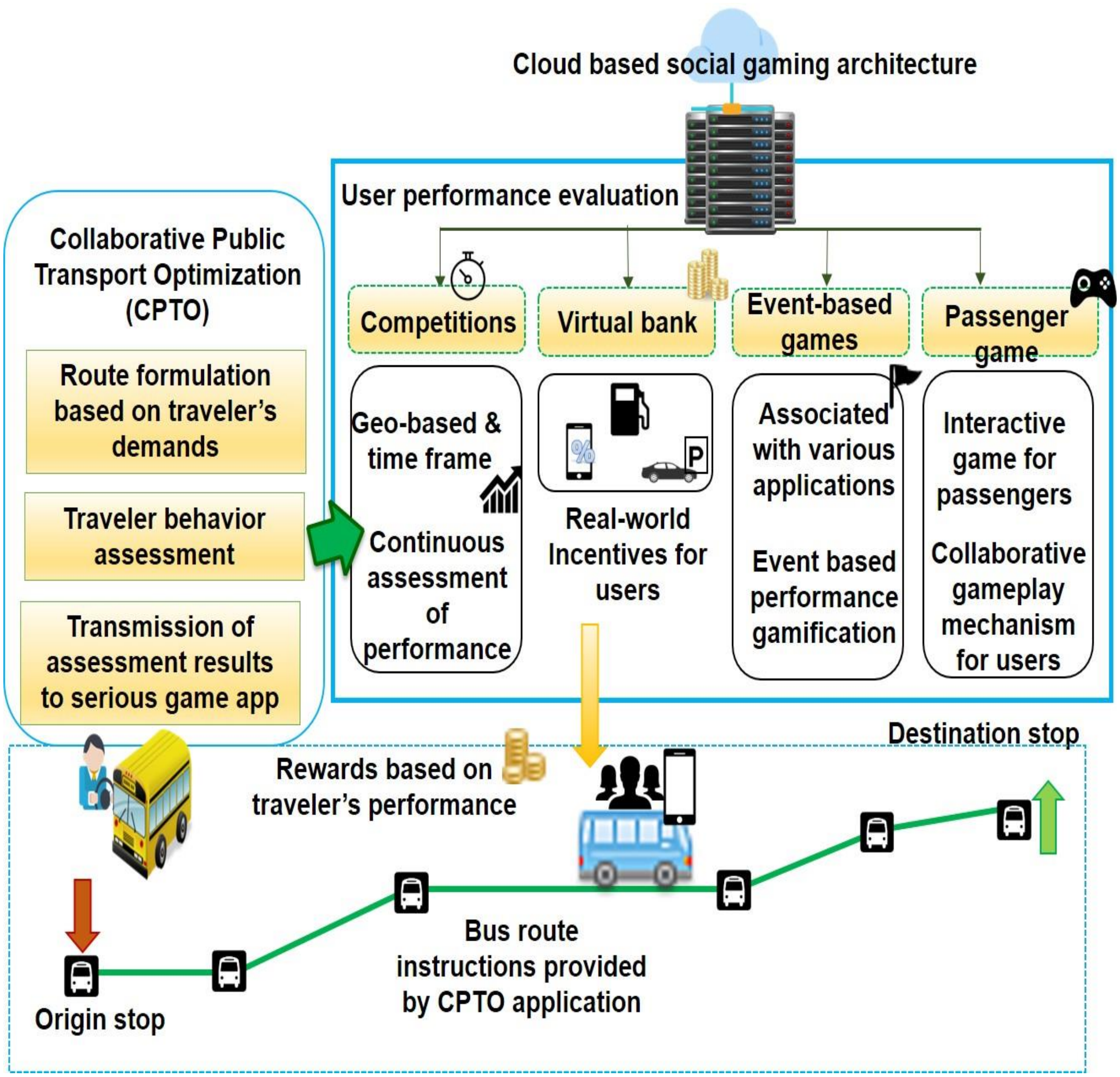


***Figure 23**: An integration module - Gamification structure to improve user behavior in public transportation systems*

In CPTO application, the traveler's behavior is gauged by keeping track of the changes among buses and stops. Before the start of the trip, the user gets the suggested route plan from CPTO application comprising the sequence of buses and stops to be taken according to preferences. During the journey, the user should follow up with the scheduled bus lines and timings to reach the destination. All these actions of traversal are assessed and based on traveler's behavior; the CPTO application manages to compute the virtual coins amount to be provided. The assessment results are then sent to serious gaming application from which the virtual coins are credited in user's virtual bank.

***Table 3**: Cases for reward/penalty identification based on the user behavior in CPTO application*

Case	Suggested bus line and origin bus stop	Suggested time	Suggested destination stop	Virtual coins reward (a > b > c > 0 > d)
1	False	False	False	D
2	False	False	True	D
3	False	True	False	D
4	False	True	True	D
5	True	False	False	C
6	True	False	True	C
7	True	True	False	B
8	True	True	True	A

In **Table 3**, the cases associated with suggested route and grading of virtual coins are provided. The assessment is performed by comparing the suggested bus and stop changes with the actual ones to find the sequence of actions which fall within the cases mentioned. By the end of the trip, virtual coins are awarded based on assessment results. The scores for the performances are calculated based on the cases mentioned above and these scores are used for competitions game logic, which was similar to the ones used to create competition for drivers. The process of incentivizing user performance through virtual coins will be a motivating factor for the users as it is connected to the real-world incentives. These incentives acquaint users with the system and provide more scope for gamification process.

Apart from virtual bank and competitions, the users can utilize other gaming services like S&L and passenger game as well. Concerning the passenger game, the game relies on the skills of the passenger in tackling the challenges in game scene and the energy factor (in case of CPTO it depends upon the number of users traveling in the zone). The game consists two levels, and the challenges on the game scene vary based on the energy factor. When the energy factor is low, the player encounters more challenging game scene and difficult gameplay. In case of SG_CB, these games aimed to estimate the driver performance through green drive evaluator and in CPTO, the game logic remains the same but evaluation pattern is designed to estimate the user performance in managing the travel instructions provided by CPTO application. Therefore, the SG_CB architecture provides adaptable systems, which can be configured by 3rd party applications to use games for improving user behavior in mobility contexts.

Chapter 6: Field Tests and Deployment Scenarios

In this section, the various field tests that were conducted for gaming applications are specified. The field of serious games application was conducted in Europe at multiple test sites (see **Table 4**). The application was tested in different car models as well, and that gave a better scope to tune the game parameters and evaluation metrics.

***Table 4**: Field test locations*

Field test	Location
Test 1	Trento, Italy
Test 2	Turin, Italy
Test 3	Gothenburg, Sweden
Test 4	Tampere, Finland
Test 5	Genova, Italy

6.1. Test 1 – Trento

The first test was conducted in Trento, Italy (see **Figure 24**) and during this test, the standard driving pattern was maintained with minimal harsh events. The vehicle signals were extracted, and the post-processing was done on these signals to understand the key signal parameters, which were involved in determining the driver evaluation module. Centro Ricerche Fiat (CRF) conducted the test session and the test site was located around the CRF campus in Trento, Italy and the test site comprised of various road segments such as urban, suburban and the mixture of both. The test site was divided into four major zones such as Tangenziale, Viale Verona, Misto and Via Nationale and expands around 13 Kilometers, with an approximate completion time of the entire session around 30 - 40 Minutes.

From this test session, it was possible to tune parameters of vehicle signals such as finding the thresholds for harsh driving, signal ranges (at it varies from one to another) and quantity of signals that can be extracted in specific time frame. These parameters were fundamental units for designing proper evaluator for estimating driver performance. The sample set from these signals were used for simulation and testing in a lab environment.

When the event analysis module was developed, the initial trials were executed based on the logs extracted from this test session (see **Figure 25**). The signals from this test were used to replicate more variations and create various signal patterns to simulate a road network and then the results were sent to the games for analysis. In experimental results, the first test, which comprised of game analysis for simulated road network (see 5.1. Game prototype 1 – Real-time gaming aspect on a simulated road network) holds basis from this test session in Trento.

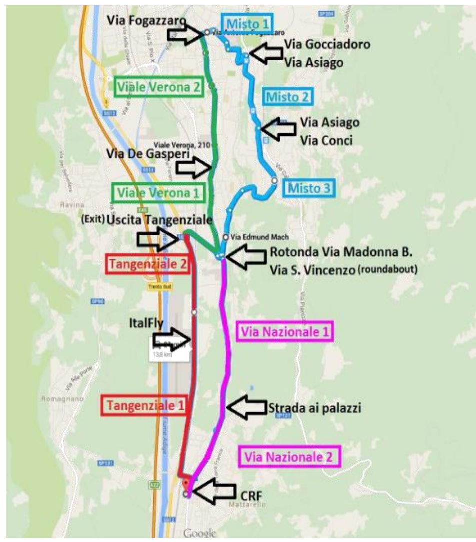


Figure 24: *Map of the test site in Trento, Italy with locations comprising of urban and sub urban zones. The red route highlighted on the map is the suburban zone (Tangenziale) and the green route is of urban zone (Viale Verona). The blue and purple routes are the mixture of urban and suburban zones.*

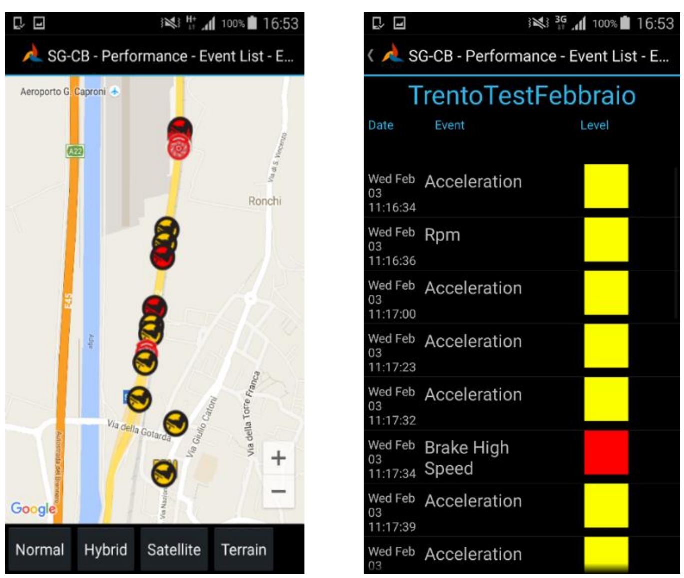
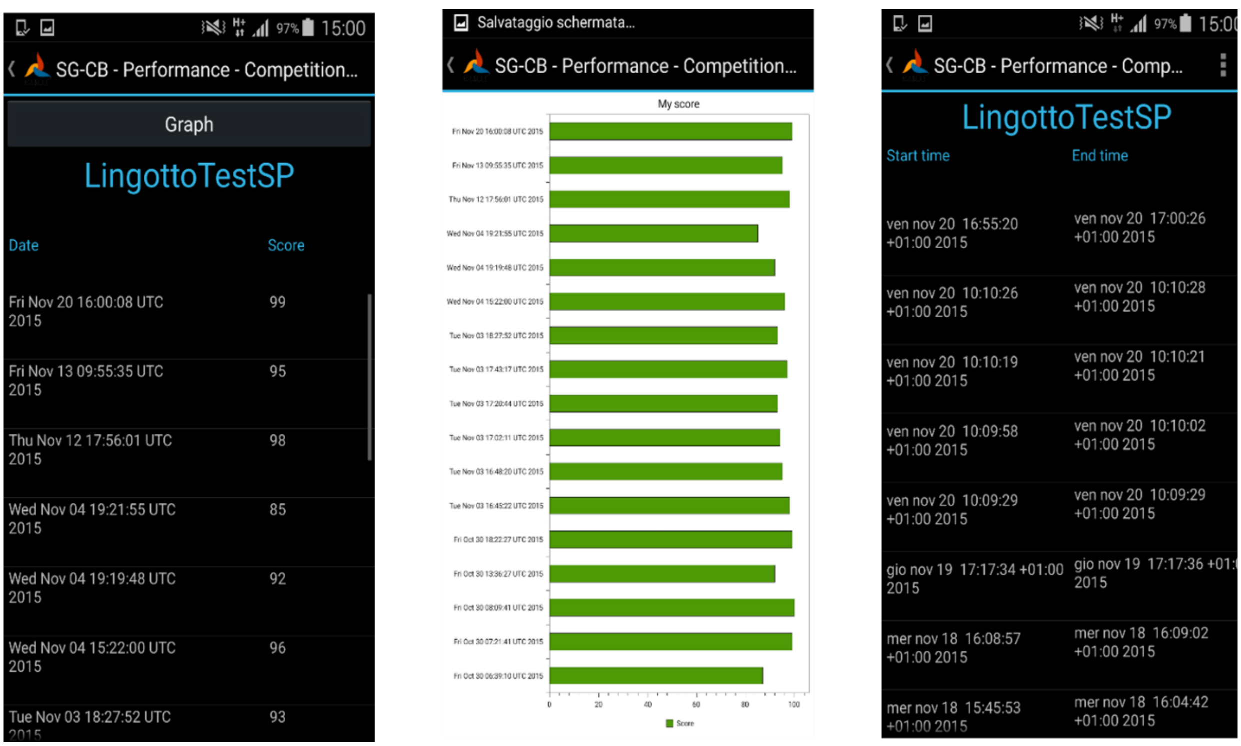


Figure 25: *Event Analysis report of Trento test - the map and list views of harsh driving events captured*

6.2. Test 2 – Turin

The second test was conducted in Lingotto, Turin. During this test, the competition game module was tested, the driver performance was captured on various competition instances. The UI elements for the smartphone application was developed, and the functionality of extracting information from cloud server and representation of results on smartphone application was tested during this field test. As we can see from below figure, the scores secured by the player on various competition instances, the representation of scores on the bar chart in chronological order and list of all competition instances that user participated (see **Figure 26**). The scenario of this test was to make users subscribe to an open competition and exhibit better driving performance.



(a) (b) (c)

***Figure 26**:(a) User scores in each competition (b) Graphical representation of scores (c) list of competition instances.*

The variety of data exchanges that happen in serious game architecture, such as user performance evaluation data transmitted from the evaluators (on vehicle and smartphone) to the cloud server for aggregation/processing and display of information on a smartphone application.

It was necessary to test this control flow to ensure the link between the modules is correct. In this field test, the user could exploit the SG_CB smartphone app (also including the social networking) to analyze the performance in competition. The representation of scores and navigation on UI was also taken into consideration. However, there was a minor problem in UI, during this test - whenever the user scrolls the menu the application hangs all of sudden and this problem was marked as high importance and necessary bugs associated with this condition was taken into account for fixing the issue.

6.3. Test 3 – Gothenburg

The test 3 was the first plug-in test in the TEAM project, and the test was conducted in Sweden on 27th – 28th January 2016. The motive was to test the event analysis module and competition between two users. Because from the previous tests the parameters in evaluator module were tuned such as the threshold ratio of acceleration and brake signals. During the test drive the Mercedes Benz(S-class) was loaded with the necessary evaluator bundles in OSGi platform and the smartphone-based evaluator, was mounted on the dashboard of the car (See **Figure 27**).

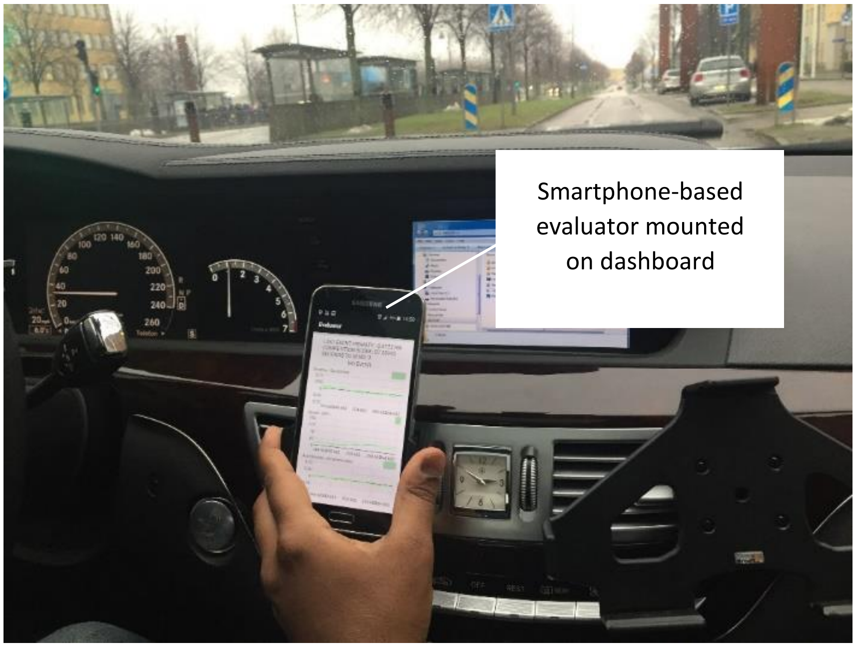
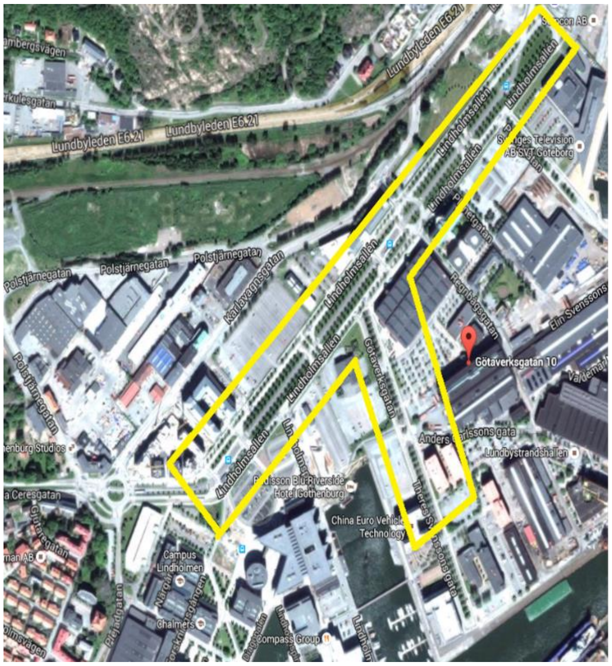
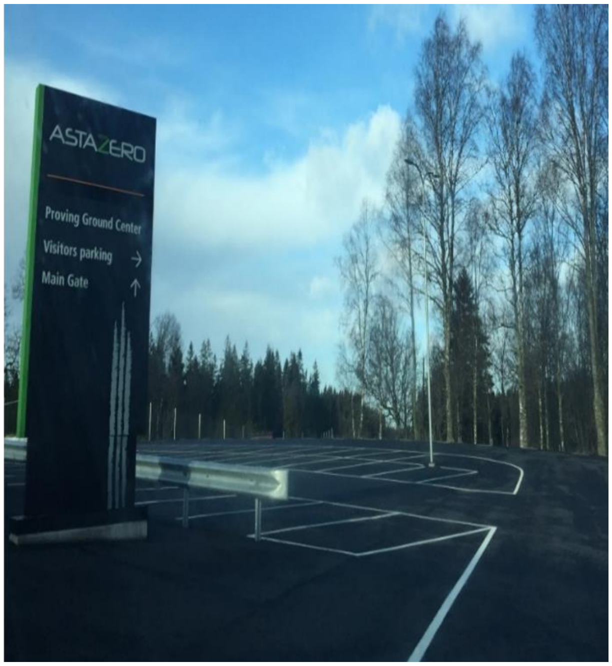


***Figure 27**: Apparatus setup for demo in Mercedes Benz – S class*

The two evaluators were in-place to assess the driver performance, and the connection between the vehicle signal evaluator module and cloud server was tested. Also, these two evaluators were used to measure the performance of individual driver, so that we can compare the evaluation parameters in post-processing. At first, the smartphone-based evaluator was tested, and the drive lasted for 10-20 minutes in Volvo premises (as shown in **Figure 28**), the drive comprised of various harsh events, such as high acceleration and harsh brakes.



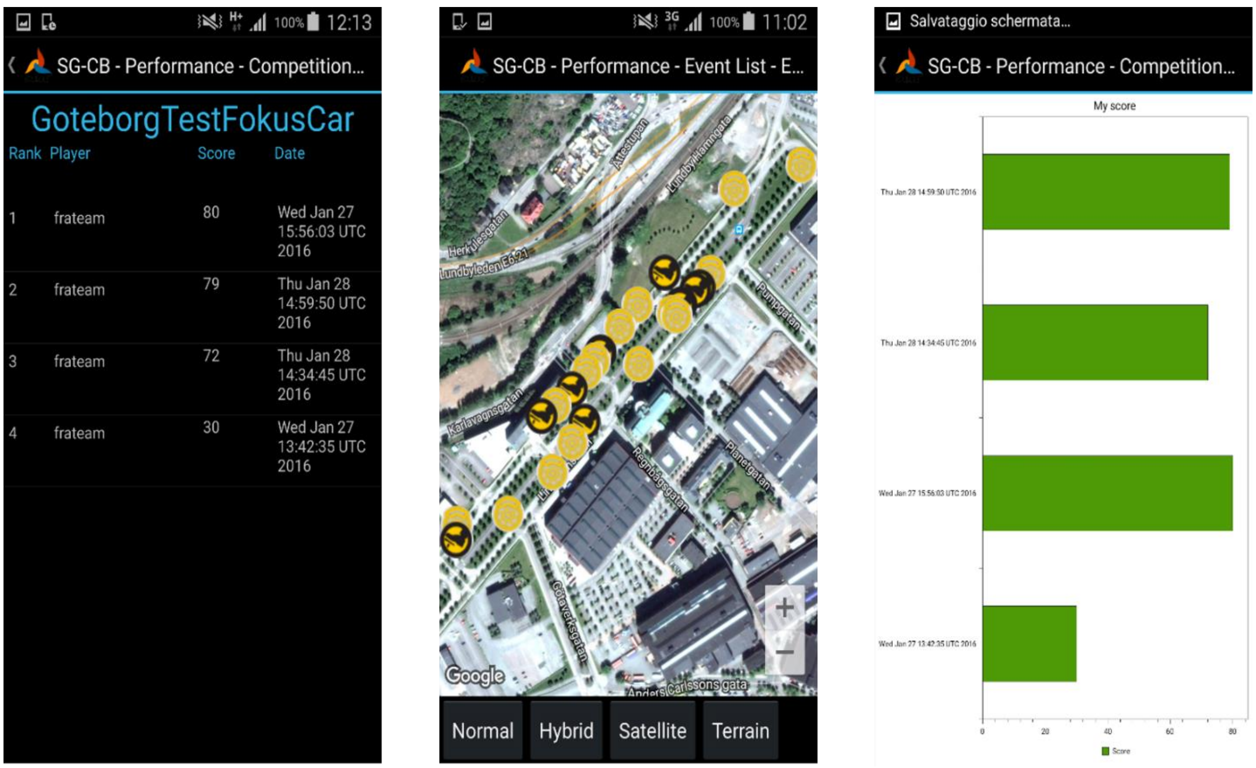


(a) (b)

Figure 28*: (a) Test site 1 - in Volvo premises Gothenburg, Sweden (b) Test site 2 – ASTA (All Service Test Area) ZERO in Gothenburg, Sweden*

The results of event analysis are displayed in **Figure 29** (b), and it can be noted that various harsh events are captured and are displayed on Google maps. However, the specific parameters of the evaluator required tuning, the more yellow markers on the map denotes that intensity of harshness is medium. But, in reality, the driver performance was harsh, and these markers should have been plotted with the intensity level of red.

On the second day, the test was conducted in ASTA ZERO test track and over here the CAN-based in-car evaluator module was tested. The performance of one user was evaluated, and the scores were represented in the competition, the control flow between the evaluator and cloud server was tested through the transmission of scores on the specific time interval (in this case it was 2 minutes). The performance was optimal throughout the drive session with minimal harsh events, the scores of competitions are listed out in the below figure (see **Figure 29** (a)).

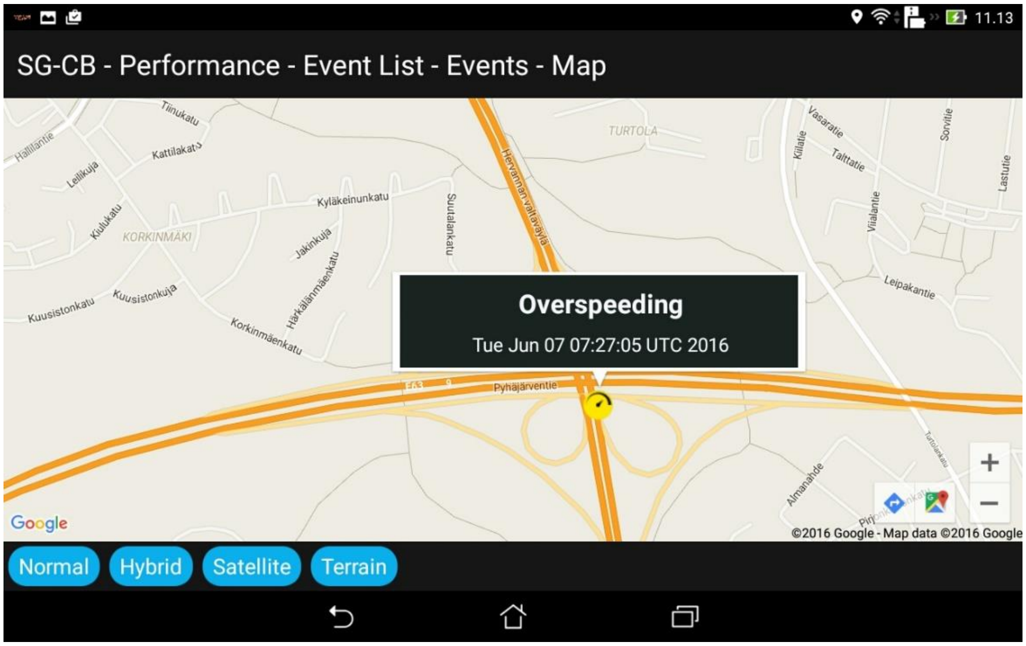


(a) (b) (c)

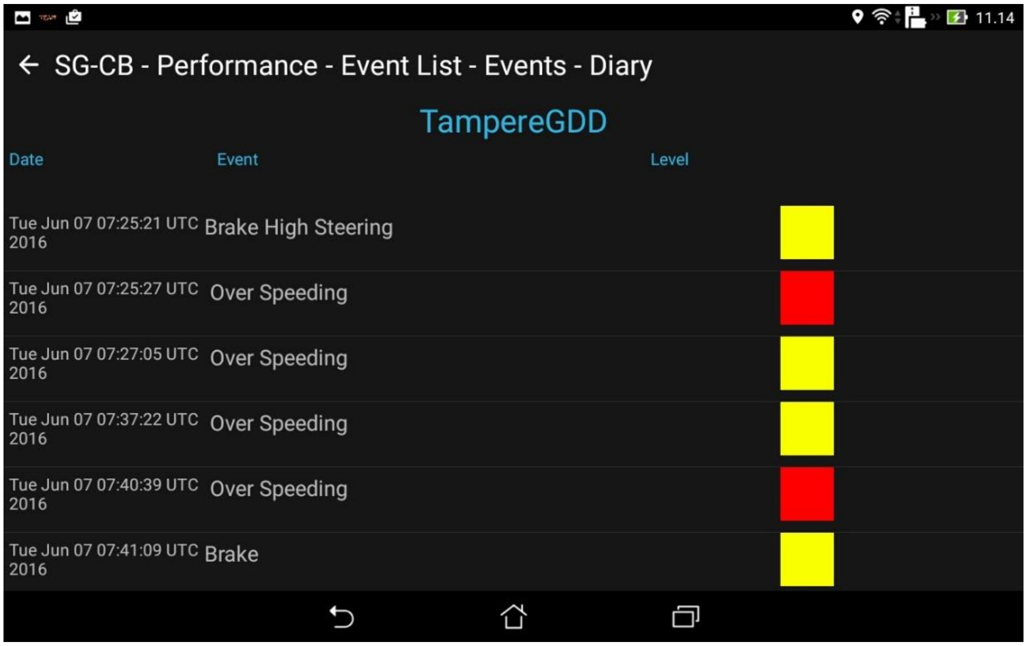
Figure 29*: (a) Scores secured by user at various test sessions (b) Representation of harsh events on google maps (c) Graphical representation - evolution of performance*

6.4. Test 4 – Tampere

The field test of event analysis with different evaluator was conducted in Tampere, Finland. The VTT research center (Finland) collaborated with UNIGE (University of Genoa) team to exploit the serious games and event analysis modules to their evaluator application (safe drive - SD), which assessed over speeding.



(a)



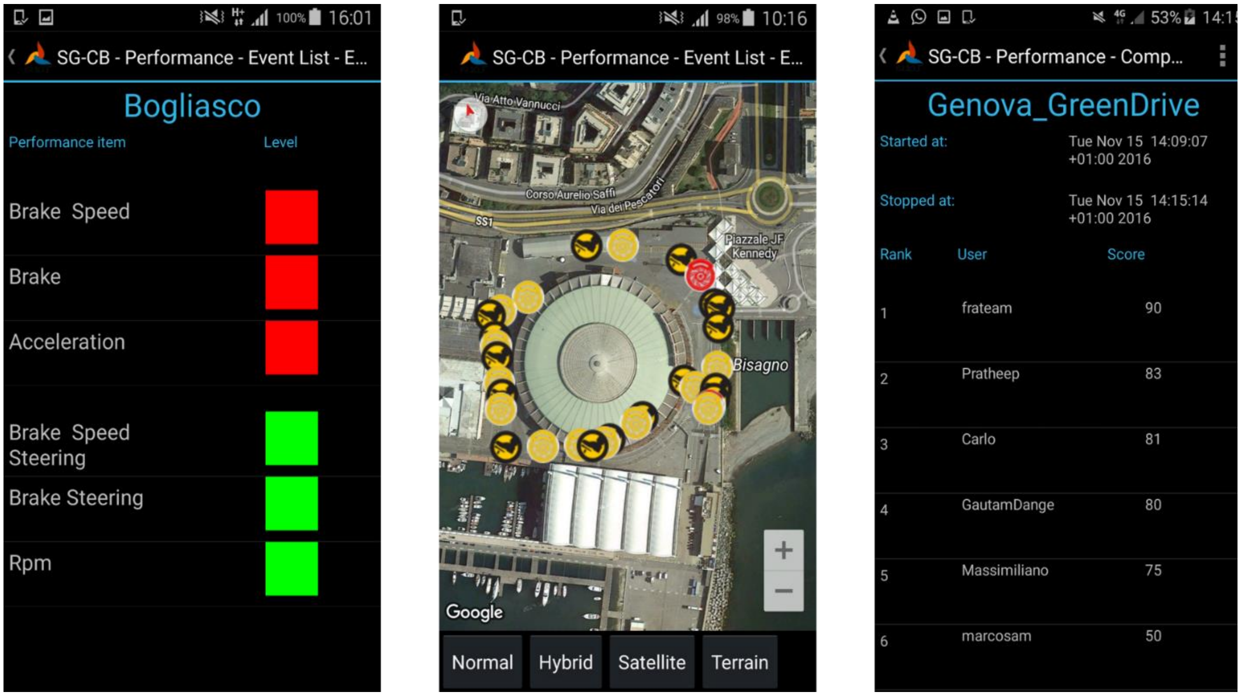
(b)

***Figure 30**: Event analysis of SD application - (a) Map view of over speeding event, (b) diary view with list of captured events*

The VTT research team utilized the necessary web services for triggering the over speeding events to our cloud server, and the event analysis module from SG_CB smartphone application represented the over speeding events on Google maps, and the diary view listed all the events that were captured during the drive along with their intensity (see **Figure 30**). This test was helpful in understanding the outcomes of plugging 3rd party evaluator in serious gaming module. The serious gaming application(SG_CB) is a centralized framework, where new applications can exploit the services and contribute to the expansion of the architecture. Through this test, the basic deployment of 3rd party evaluator was tested and it can be noted that not only new games but also new evaluators for assessing various user behaviors can be plugged into SG_CB module.

6.5. Test 5 – Genova

After various field tests and simulations in a lab environment, the bugs associated with evaluators and smartphone application were resolved. The key issues such as the display freeze in smartphone application, parameter tuning in evaluators, sensitivity of event analysis module and few other issues related to web services were resolved. To test all these on real-time drive scenario and to ensure the better functionality of the system, several field tests were conducted in Genova, Italy. The first test was conducted in Fiera Di Genova, the drive comprised of various harsh events and post-drive the event analysis was checked to see if the harsh events were marked properly. The evaluator was much improved compared to the Gothenburg test (6.3. Test 3 – Gothenburg), and some harsh events of brakes were captured (see **Figure 31**). The competition part was also tested to ensure the variation in scores for poor performance. Further parameters were tuned in evaluator module after the test.



(a) (b) (c)

***Figure 31**: (a) Summary view of events (b) representation of harsh events on google maps (c) Competition results of various users ranked on the basis of their performance.*

6.5.1. The Field test of real-time games

The real-time games (DG and PG) were developed by June 2016, and initial field test of these games was performed in public buses in Genova, the smartphone-based evaluator was mounted near the driver, and another smartphone interface with the game scene was tested to ensure that the games are reacting for the real-world driver performance.

Figure 32*: in-vehicle smartphone-based evaluator transmitting scores to driver game scene on test drive in public bus-Genova*

The preferred test routes were from Corso gastaldi to Borgoratti in Genova, the route comprised of narrow roads through the terrain and this was the ideal path to test the varying driver performance, as there can be rapid acceleration and sudden brakes (see **Figure 32**).The driver game was tested for a drive from Corso Gastaldi – Borgoratti and passenger game was tested way back from Borgoratti and this field tests lasted for 3 weeks on the same route (see **Figure 33**). The games required more sensitive inputs and the game parameters such as modulating the game scene based on driver performance and displaying the predictor gauge in driver game were modified. Also, these tests gave an understanding of evaluation pattern and scoring metrics for both the games, as in how well the driver performance can be in reality. It was also a necessary aspect to tune passenger game to accommodate for buses because in future deployment the game should be more adaptable for the passengers in buses and cars. The driving pattern in buses differ a lot compared to the cars, so these tests gave an opportunity to analyze the difference between various drivers. When deploying the real-time games, the major consideration should reflect upon the adaptability and usability of games, as wide range of users should be able to play games on various driving scenarios. For more details on the games and field tests see Demonstration and video links.

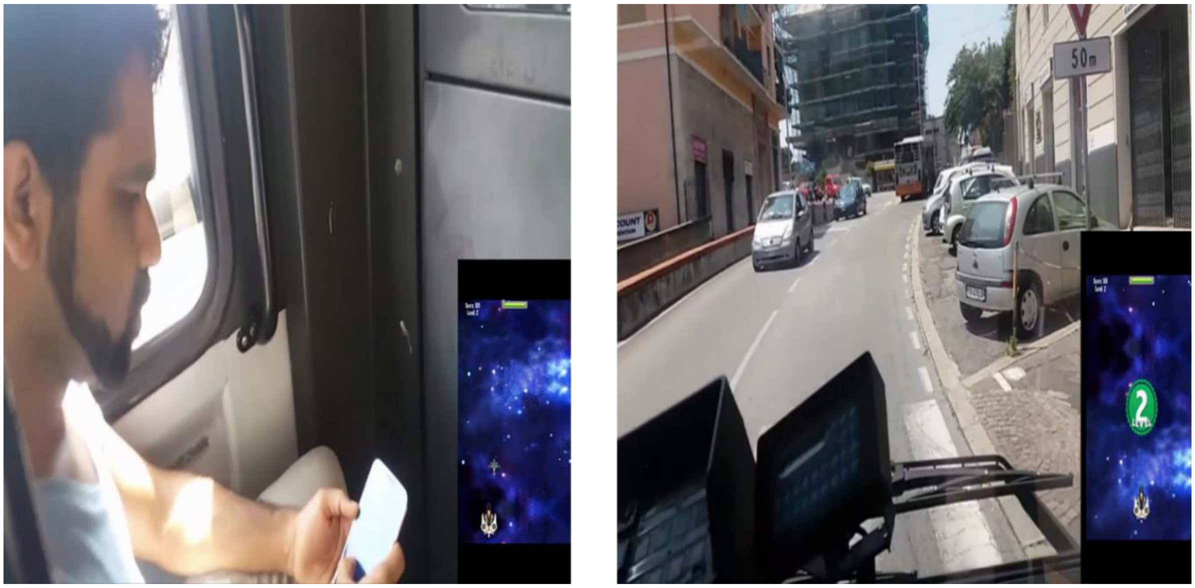


Figure 33*: Initial field test of passenger game in public bus with usability test and analysis of game parameters*

On the halfway mark during this field test, a separate pilot test with 10 users was conducted in Fiera Di genova for driver and passenger games. The test users were students from the University of Genoa, and the primary aim of this test was to analyze the functionality of the game designs and user opinions of the games. During this test, I understood that users faced difficulty in establishing the Bluetooth connection with smartphone-based evaluator module. So, in this case, both the games had minor configurational issues corresponding to Bluetooth connectivity. Then I underwent a debugging and modification phases, where I removed the Bluetooth module and interfaced the games directly to the cloud server. In updated architecture, the games interacted with cloud server to extract the driver performance results, so this methodology resolved the tedious configurations of Bluetooth and launched the games and all configurations with just one click.

Another issue concerning driver game was the display, as initial UI was more detailed with levels, scores, lives and gauge the view was more distracting for the driver. So, I analyzed various solutions and developed two views, where the detailed status view is hidden under the driver view (The UI scene, which is on upfront), an audio feedback was introduced, where the driver gets feedback on a timely basis, and the game was made to be non-interactive.

The driver gets notified about the performance, and the driver view has a big gradient window, which shades from pale yellow to green on a better performance. However, the driver can check the performance through a status view while waiting at traffic or at the end of the trip (see **Figure 34**).

Figure 34: *Snapshot captured from the field test of updated driver game interface*

The passenger game had issues related to the screen ratio, as it did not fit for all screens and initially, it was designed only for mobile interfaces. During the field tests, it was good opportunity to analyze the user needs as well. While designing UI elements for the interactive games, the major consideration should remain even for the screen resolution, and games cannot be restricted to particular display settings. The game configurations and parameters need to be pervasive and adaptive towards the user needs and specifications. When targetting for more number of users, the game design aspects must consider a large-scale deployment factors and one such is fitting the game scene in all types of displays. The passenger game settings were made to adapt as per the user device, and the game scene can adjust automatically between the mobile and tablet devices. After resolving these issues, another field test was performed for 15 days, and it was a drive from Albaro to Bocadasse. During this test, I ensured that the control flow between games and cloud server is good, and the reaction of games towards the real-world driver events is satisfactory. There was a separate session for recording video for the TEAM project final meet. For the video, we performed a comparative study of two user performances, where one user maintained optimal driving behavior and another user exhibited harsh driving behavior (see **Figure 35** and **Figure 36**).

The comparative study was tested for competitions, event analysis, driver game and passenger game for varying driver performance (see Demonstration and video links). Finally, the preparations were made for the usability test, and multiple users were scheduled for a test drive from Albaro to Bocadasse. The users had the opportunity to play games and test the impact of games for varying driver performance.

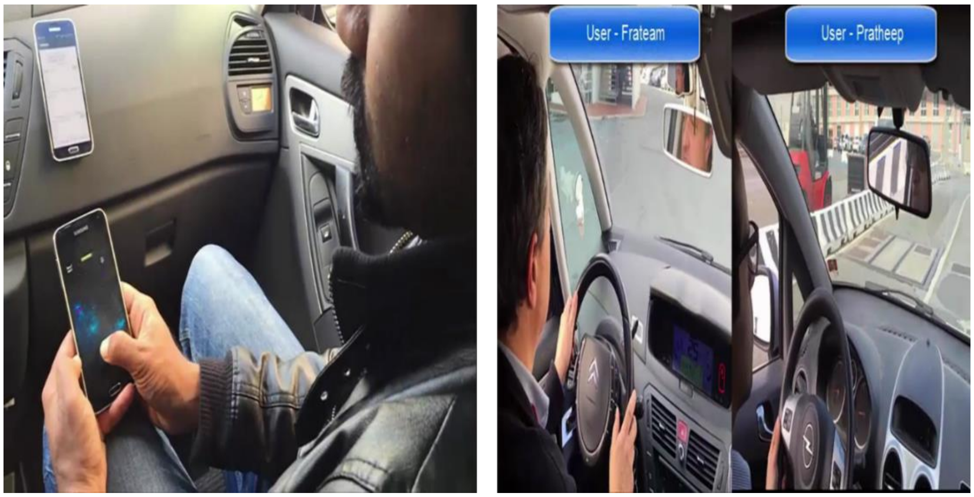


***Figure 35**: (a) passenger game demo on real-time driving session in car (b) Real-time comparative testing of two users and the picture was taken from the video demonstration for the final event*

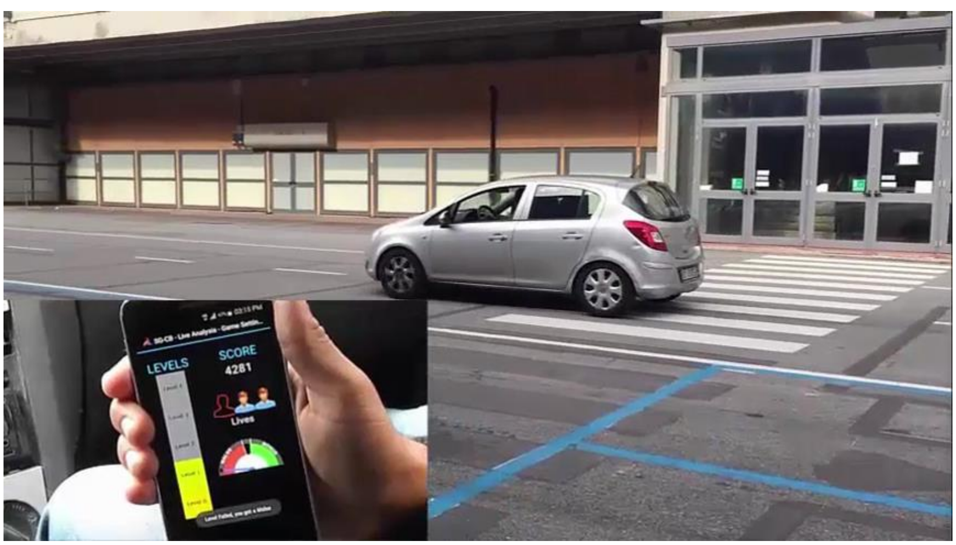


***Figure 36**: Driver game scene indicating the impact of poor driving performance - the picture from driving session while the driver was exhibiting harsh brakes*

Chapter 7: Experimental results and analysis

7.1. Analysis report for Game prototype 1

The initial deployment study was conducted on the application of games on real-time drive scenario. To analyze the gaming functionality with more users in a competitive scenario, a road network of 40 users was simulated. The test drive log signals provided by CRF were used to simulate the signals for 40 cars, and little randomness was introduced in the vehicles considering the varying behaviors of the users. Based on the simulated behavior the scores were provided by the evaluator, and these scores were sent to an aggregation server, which computed the individual user performance along with the peers (see **Figure 37**).

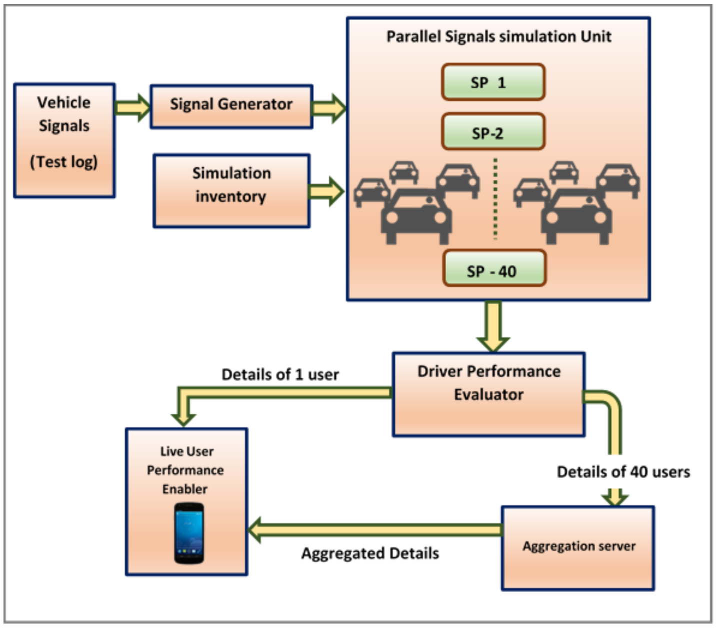


***Figure 37**: Components of Vehicle Simulation Unit and control flow of the Game Prototype 1*

The representation of user performance happens in two stages where the first phase involves the display of absolute scores (individual performance) and the second phase involves the display of the relative scores of the users (Social comparison along with peers). In the second phase, the smartphone application requests the Aggregation server for the latest and historic averages of users on the road link. The response of the Aggregation server is then assessed with the absolute values secured from the Vehicle simulation unit and are displayed on the gauges with the grading scale of good, average and bad.

The feedback methodology enables the comparison of user performance with the peers on all aspects of the Green driving and Fluid traffic, apart from the estimation on gauges, the performance measured (respective to various links) are then plotted on Google Maps (with coloring grade based on performance) for more insights in performance.

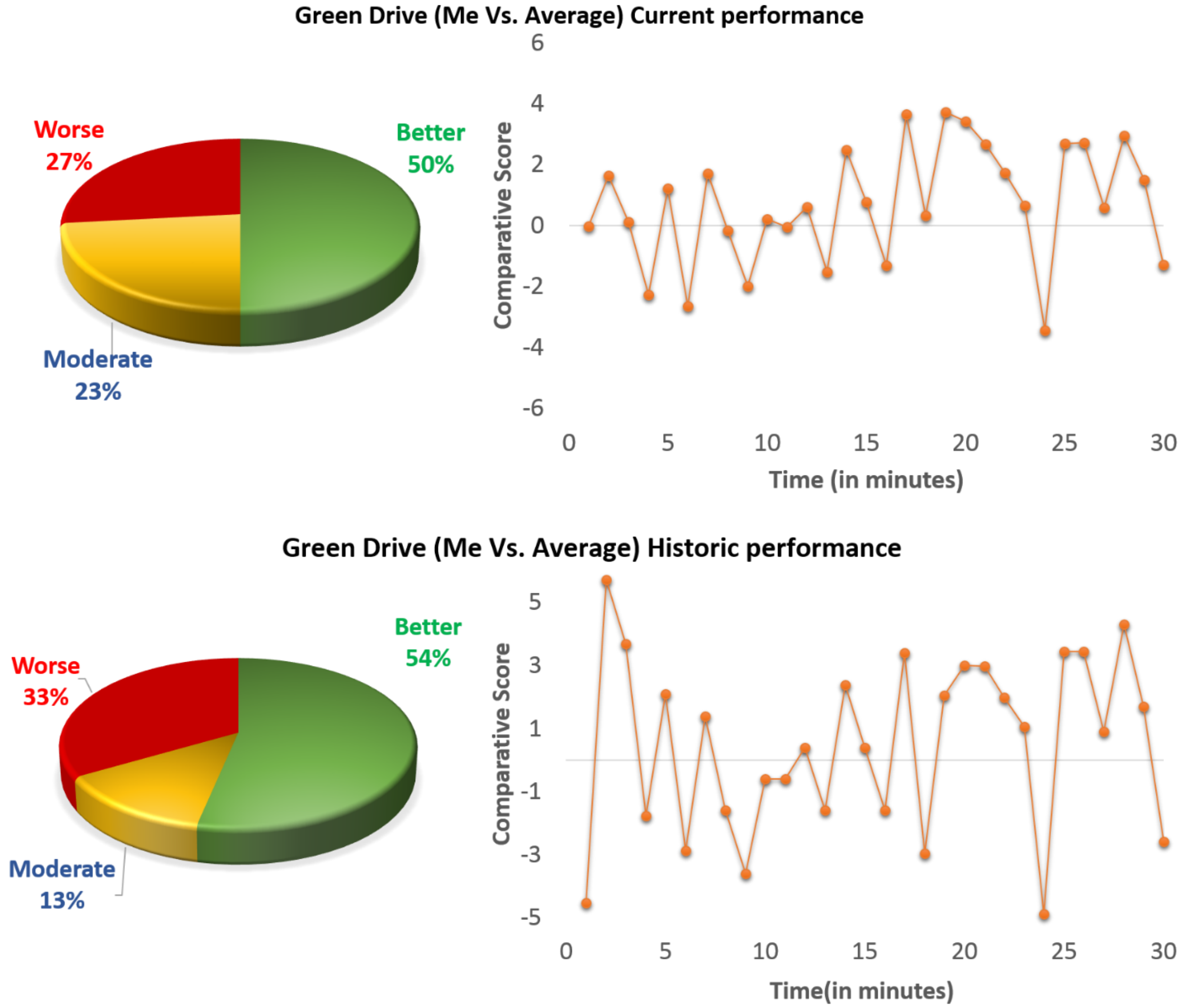


Figure 38*: Consolidated Social comparison analysis of Green Drive with current and historic user performance comparisons*

The main idea of comparing user performance analysis with the performance of peers was for deriving the detailed analysis of individual user performance.

As the analysis involved two different aspects (Green drive and Fluid Traffic) and the simulation test scenario consisted of samples collected for 30 minutes with the update frequency on the timestamp of 60 seconds.

The average values of all the users in various links (Geo-referenced zones) are tabulated in the Aggregation server, and the individual user performance (absolute) value is extracted from the vehicle simulation unit. Finally, these two values are compared to understand how well the user had performed.

The historic performance is the accumulation of scores from the start of the competition, and current performance is the accumulation of scores for last two minutes (recent). The line chart represents the outcome of a comparison between individual performance (Me) and Average user performance (see **Figure 38**). The values below zero are the places where the user performed below average and the points above zero are the places where user exhibited better performance compared to the average. The pie chart denotes the overall performance of the user in comparative scales for historic and current performances. Also, the scores are converted into the qualitative scale of better, moderate, and worse – where the user visualizes the outcome on gauges and map.

From the above charts, we can see that there was a slight rise in better performance when considering the historic records. So, the pie chart summarizes the overall user performance in current/historic records on the scale of better, moderate and worse. However, the moderate performance ratio had decreased, and the ratio of poor performance had increased in historic records. Whereas in current records the moderate performance was more compared to poor performance. This denotes that there was higher variation in individual performance, which accounted for the overall loss in performance in historic records.

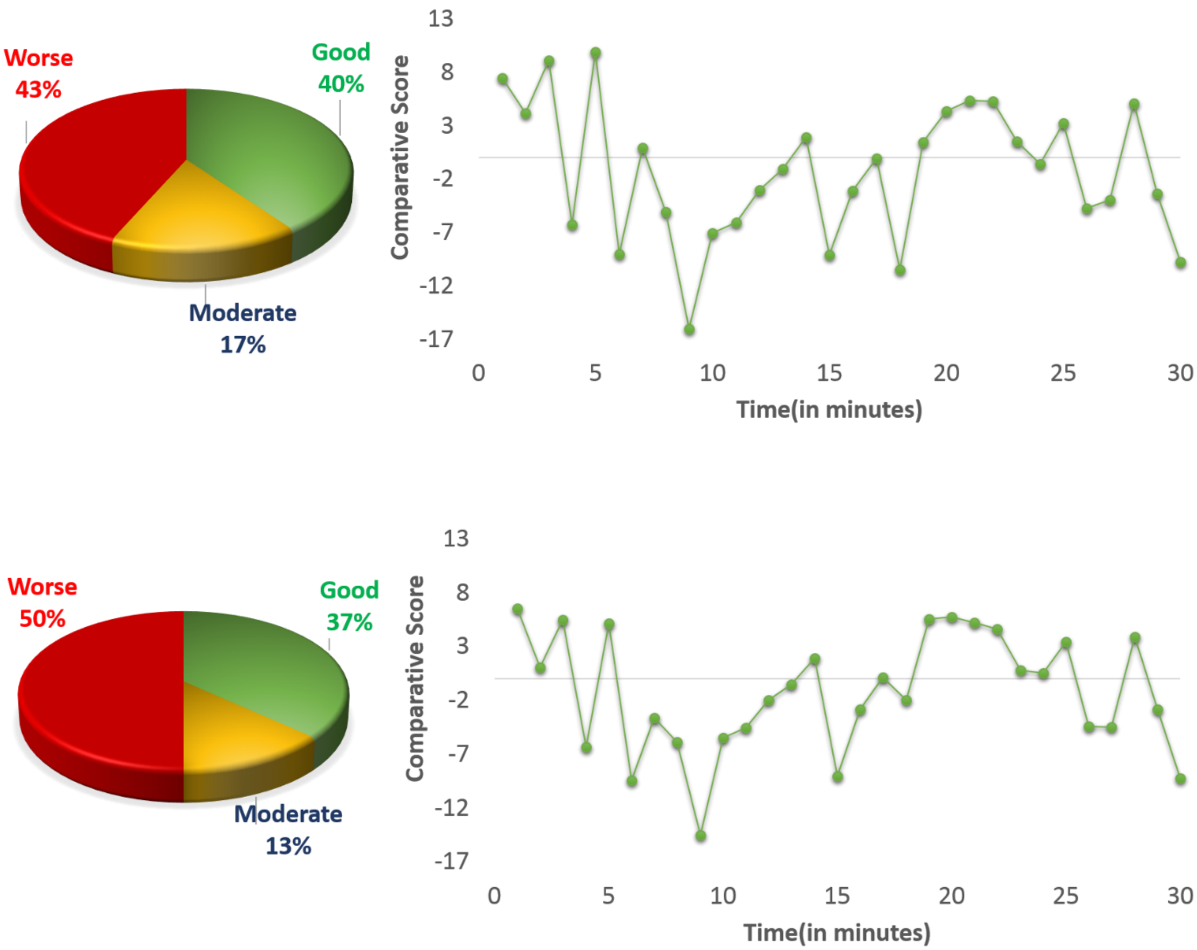
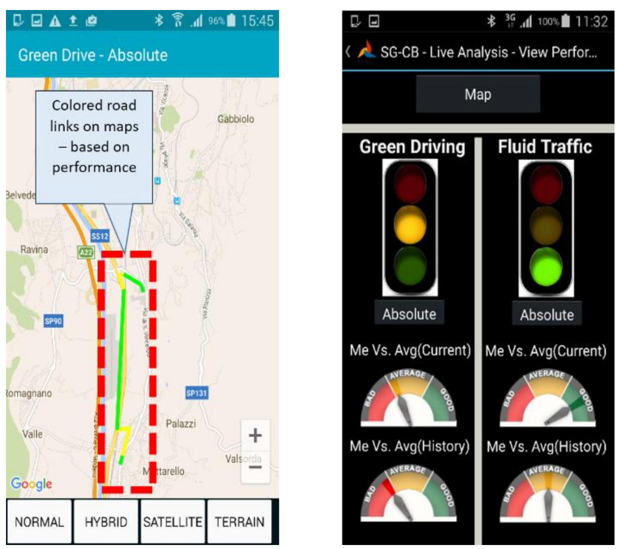


***Figure 39**: Consolidated Social comparison analysis of Fluid traffic with current and historic user performance comparisons*

Let's consider the fluid traffic aspect and from the above figure (see **Figure 39**), it can be noted that the ratio of poor performance is more compared to green drive. From this sample test scenario, the comparison scales of green drive and fluid traffic denotes that the user needs to improve the driving aspect related to fluid traffic more than green driving. On real-time basis, this comparative methodology will give deeper insights into driving aspects of the user. The results of the analysis are represented spontaneously on Google Maps (see **Figure 40**) and this would also inform the user about the locations where the driving pattern can be enhanced. The social comparison can highlight the poor driving performance and also reinforces the users to perform well during the drive session. Therefore, this method provides an in-depth analysis of user performance on two scales (absolute and social comparison), and this can be deployed in real-time for creating a qualitative grading analysis of user performance.

The methods used in the simulation environment could be transformed to the real-world platform by discarding the vehicle simulation unit from the architecture and direct transmission of the vehicle signal evaluation to the Aggregation server. The individual user can utilize the live user performance enabler application and fetch the performance analysis report directly on the smartphone application with the reference values from the Aggregation server. Henceforth, the methodology which was implemented emphasizes more on a comparative assessment of user performance on absolute and social aspects. This way of gauging user performance would uplift the entire cluster of users coupled to the serious game framework, as the betterment of driving behavior with one user would impact on all the users associated with it, thus ensuring the collaborative enhancement of driving standards.



(a) (b)

***Figure 40**: (a) Performance representation on road links (b) Performance display through various gauges*

7.2. Analysis report - The first plug-in test

After the simulation tests, the modules were prepared to be deployed on the real-time driving scenario. The first plug-in test of the application was conducted in ASTA ZERO (Active Safety Test Area) test track in Gothenburg, Sweden on 10 March 2016 (as stated in 6.3. Test 3 – Gothenburg).

The BMW sedan and a Samsung Galaxy S5 smartphone (with the SG-CB application installed on it) were equipped as part of apparatus setup, and the smartphone was mounted on the dashboard. The test run comprised of two laps on the test track, out of which the first drive (Lap 1) comprised of bad driving behavior with frequent harsh driving events and the second lap comprised of optimal driving performance with a minimal number of harsh events. Each lap lasted approximately for 20 minutes around the same locality.

The main consideration behind these two types of driving style is to compare and estimate the quality of driving and to test the functionality of the implemented system. In precise, I wanted to analyze the insights of the event analysis for varying driver performance. The event analysis is the driver coaching module and thus having a solid evaluation pattern with proper visual feedback can be more efficient for the users to understand their driving behavior.

Through this separate evaluation for the course of events that driver exhibited during the trip (events such as harsh braking, high acceleration, and RPM levels) and the captured harsh events were sent to cloud server along with their geo-references and later these events were retrieved and displayed on Google maps in Smartphone.

The vehicle signals and the evaluation results from the green drive evaluators (the Instantaneous and smartphone-based evaluations) were extracted. The results of these two laps are analyzed independently in this section, and at first, place let's see the outcome of bad driving behavior by comparing the event analysis data acquired from the signal evaluator (see Figure 41). The signal evaluation metrics focused on the green drive and for which, the rapid high values of these vehicle signals were tracked, as they can occur during the rash driving behavior.

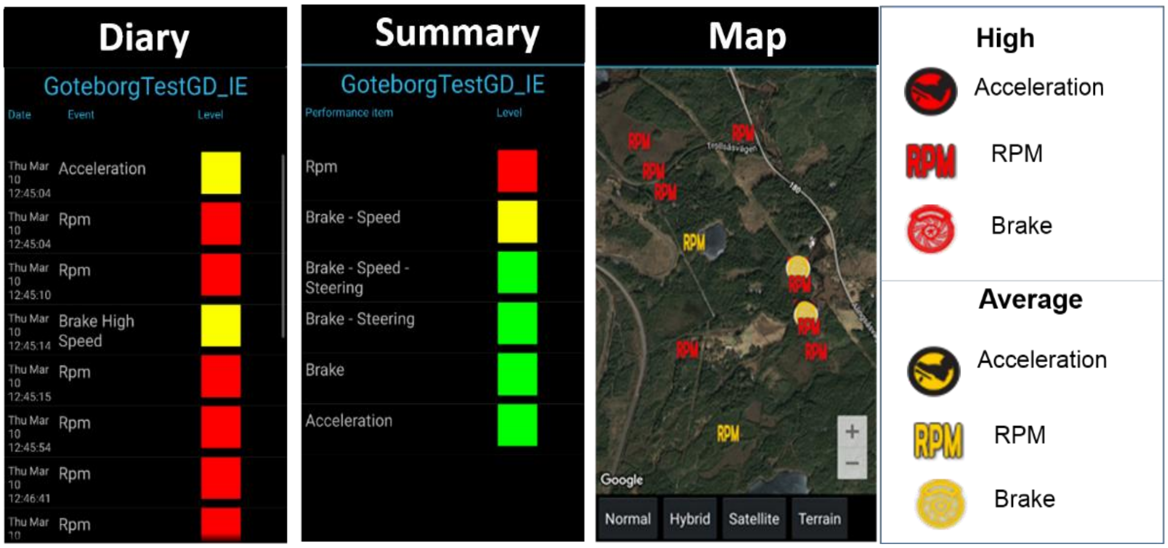


***Figure 41**: Event analysis results of instantaneous evaluation for harsh driving behavior*

The harsh events of the brake, engine RPM, and acceleration are projected on the map, and each evaluator holds a different grading pattern such as the instantaneous evaluation processes every single vehicle signal acquired from CAN bus (Controller Area Network) and looks for high values and classifies them. The smartphone-based evaluation exploits the GPS (Global Positioning System), accelerometer and gyroscope of the smartphone to determine the harshness in the driving pattern (by evaluating the acceleration and brake signals). These two evaluation methods form a solid base for assessing the driver behavior and providing the user with a detailed analysis of harsh events. We can notice ample number of events on the map from the evaluators (see **Figure 41**).

Let's analyze the second lap of the test run comprising of the optimal driver behavior. As there was not much scope of harshness in the driving pattern, the evaluator had captured less number of events during this test session in lap 2 (see **Figure 42**) compared to lap 1 (which comprised of bad driving behavior). The event analysis acquired from both the evaluators show the optimal performance of the driver on aspects such as smooth maneuvers, less exhibition of harsh events and overall maintenance of nominal driving pattern.

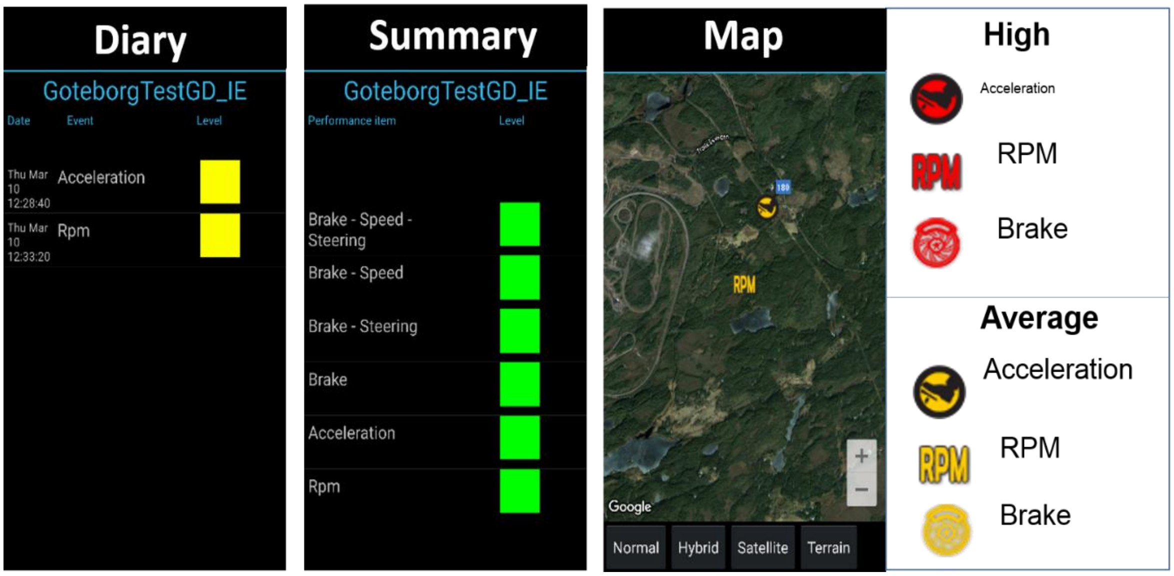


Figure 42: *Event analysis results of instantaneous evaluation for optimal driver performance*

The represented the results from the test drive comprised of good and bad driver behaviors, and the main emphasis was on the fact that the gaming aspect gives a bigger space for the users to understand the driving context and enable the users to develop their driving standards, especially when the performance is low. The incentives of the gaming aspect and representation of status on the HMI (such as gained virtual coins, events on map and competition scores) [139] will entice the users to perform well. As the rewards will motivate and downfall in performance will spotlight on the sectors of driving pattern of where the driver can rectify and improve. So, the event analysis approach creates an awareness of individual driving performance with a detailed statistical report of the drive.

7.3. Analysis report SG_CB and CPTO integration

After the simulations for configuring and tuning the system, real road tests were conducted in Trikala with five users, aged 20-50. The Tests involved a pre-test usability questionnaire and a post-test questionnaire. The road experience involved six use cases: Event-based route adaptation, Headway adaptation, Input data from travelers, En-route information to travelers, Pre-trip information to travelers, Traveler/player assessment.

The goal of the test was a functional verification of the whole system in the authentic context of use and the identification of positive features and drawbacks to inform redesign and future design [141].

During the tests, the time-stamped information such as game sessions length, scores, assessment values, and levels was recorded, and the extracted data was exploited in the large-scale deployment simulation described in the next sub-section. For the real-time tests in Trikala, the game results of 5 users (TRA01, TRA02, TRA03, TRA04, and TRA05) were extracted and are discussed in the following part.

Performance details of the 5 users from 18 competition instances are represented in **Figure 43**. The results show that User-2 (TRA02) has been consistent throughout the test and constantly excelled in most of the competition instances. The other users contributed better performance in certain competition instances with a ranging pattern of scores. Especially, User-5 (TRA05) and User-3 (TRA03) performed the least with minimum score on most of the competition instances. These are extremities of performances in a competition, and when the number of users increases, the competitive traits among the users are expected to grow with more variation in performances, and thus engagement for the participants.

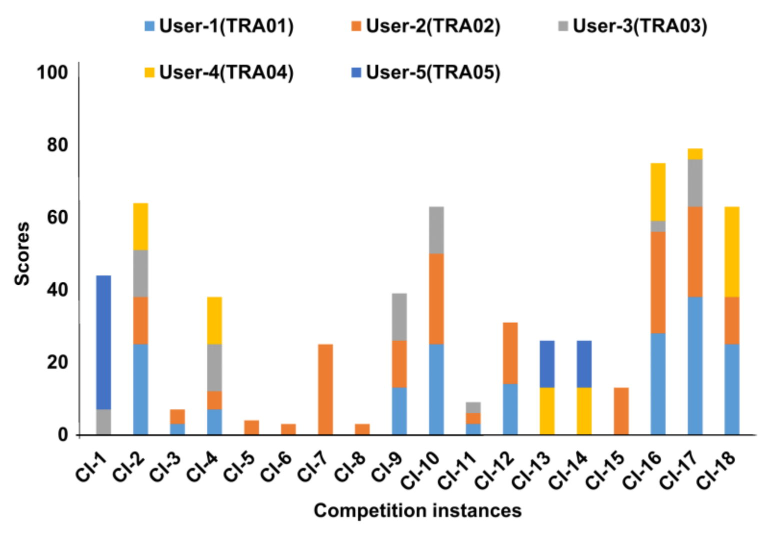


***Figure 43**: Scores secured by 5 users in 18 Competition instances (CIs) conducted in Trikala.*

Figure 44 represents the performance report of the users from the S&L game. The game comprises two levels and the average user scores at the two levels are displayed in the graph. Like in the Competition game (**Figure 43**), User-3 and User-5 did not perform well and failed to progress the level in the S&L game.

The users who cleared Level 1 (User-1, User-2, and User-4) and progressed with Level 2, were following up with the gameplay and despite the drop in the scores at some points, the overall performance in the game was optimal.

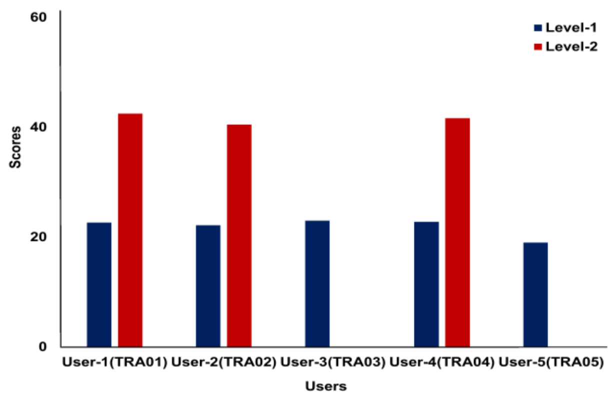


***Figure 44**: User performance details from event-based game (snake & ladders)*

The real-world events determine the possibility of favorable happenings on the S&L gameplay, and thus the impact of user performance deeply affects the player progress in games. For the tests, the Trikala local municipality provided the reward for the winner with one-month free access to the public swimming pool. These real-world incentives are deemed important for the previously mentioned virtuous cycle targeted by the SG_CB application.

In **Figure 45**, the user profile(frateam) from SG_CB database is represented with the percentage of virtual coins acquired from the applications associated with mobility (parking, navigation, and driving) based on the user performance. For testing the system, the frateam profile was created and various integration tests and real-time test results were recorded in this profile and just to give a high-level view of the integration of gaming application with other mobility applications, the number of virtual coins gained from other applications are represented. The supply of virtual coins depends on the basis of assessment, like periodic assessment (every 20 minutes) or event-based (relied upon good events exhibited by users).

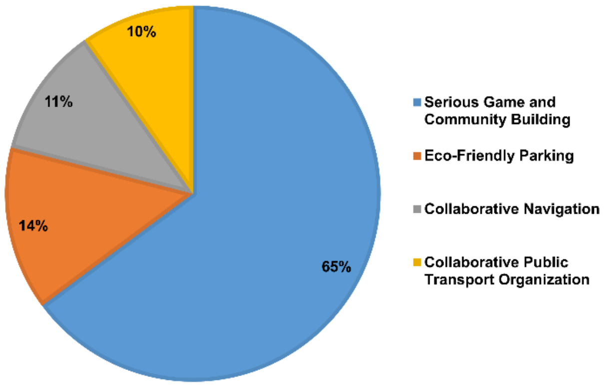


***Figure 45**: The frateam user profile with accumulated virtual coins from various applications*

To understand the expenditure of virtual coins on real-world applications, a simulated option was created to spend virtual coins from the SG_CB - smartphone application. **Figure 46** displays the total amount of virtual coins spent on simulated real-world applications (parking and bus tickets). This feature can be added as a key element by collaborating with telecom operators and public authorities for providing various benefits for the users. Integrating these benefits and allowances to smartphone application facilitates the ease of use and promotes the management of incentives from various applications as well.

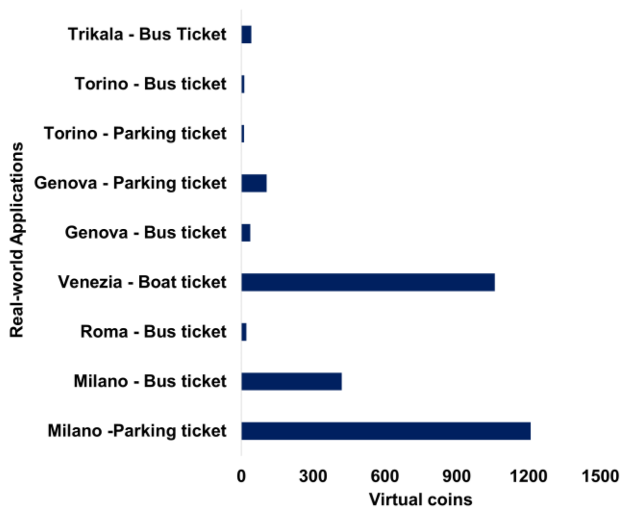


***Figure 46**: Amount of virtual coins spent on real-world applications (simulated option)*

The whole idea of field test was to understand the impacts of gaming application in public transportation and to test the integration of the CPTO and SG_CB application. Additionally, the information extracted from the test with 5 users supported the preliminary study on the impact of serious games application. The information collected from the 5 users' gameplay was used for analyzing the development of gaming applications to enhance the user behavior in the public transportation services.

7.3.1. Large-scale deployment analysis by tuning the game parameters

User tests in Trikala provided information about impact and performance in the games. The analysis was extended through simulation to consider the case of a larger number of users. Until now, the consideration was for only one factor: individual user behavior, which was mapped to score directly (in the Virtual Bank and Competition game logic), or indirectly (in S&L, there is a tunable chance factor at each roll of dice), or to energy (in PG). However, the overall mobility system also benefits if the number of bus users is high. Thus, the second factor is introduced - the number of current users, which could be captured by a flexible game mechanic such as energy. In PG, as the player energy increases, the player's gameplay becomes better, increasing the ability to combat enemies and clear levels. In S&L a high-energy player can roll dice with a greater probability of higher outcomes.

Another factor that could be considered in a collaborative framework is the performance of the close-by users, which could also imply collaboration, as a player may help a neighbor (e.g., on the same bus) to perform better.

In a game context, team effects could be spurred by dividing the city into zones and considering area borders for energy computation. In a first attempt, the energy of a player is defined as follows.

$$E \ = \alpha \times (0.8 * IP + 0.2 * AZP_x) \times (1 + CF_x)$$

The energy (E) for each user is given by his performance (IP, computed through the virtual sensor specific metrics, such as that of **Table 3**) and average zone performance (AZP_x), multiplied by the Crowd Factor CF_x in the zone x. CF is a percentage linear in the number of users, centered on 200 (i.e., 100% in case of 200 users). α is a coefficient useful to tune the overall effect of energy on the score (considered as the most important indicator in a game).

The player gets advantages when more CPTO users are present in an area. According to the formula, the number of users always represents a boost to the energy, in order not to demotivate the user in case of few users in an area.

The energy gets transformed in scores, but depending on the actual user ability in the specific situations, also exploiting his energy. Having maximum energy can withstand the duration of gameplay and offer players with more chances to complete games.

To further assess the impact of energy in games, a scenario was formulated in which the user (playing the PG) travels for 90 minutes through three different zones that vary in number of users. The travel cases are: the user goes through a zone of 50% users in 0-30 minutes; 20% users in 30-60 minutes; 80% users in 60-90 minutes. In **Figure 47**(a), represents the energy distribution for the 90 minutes journey corresponding to the percentage of users present in the zone. The drop in peak values in **Figure 47**(b) denotes that the player had failed in games and with low energy values, the player undergoes difficulty in completing the games. For the travel during 30-60 minutes, the user is assumed to travel in a zone with less number of users (20%) and this effect can be seen in scores graph where the values had grounded to zero on many instances. The low energy levels affect the games by causing the player to get low scores and failure to achieve milestones. In a real condition, we would expect that the user would not play so frequently as in the simulation. For playability, some special events may be given in similar conditions, to encourage the few users, while keeping the rule of rewarding contexts with lots of users.

Finally, on the last slot where the user travels in a zone with a highest number of users (80%), the positive effect in gameplay can be visualized in scores graph with a gradual increase of scores in games due to higher energy levels. The PG requires the skills of player to manage the gameplay, and the energy levels are a contributing factor for player performance.

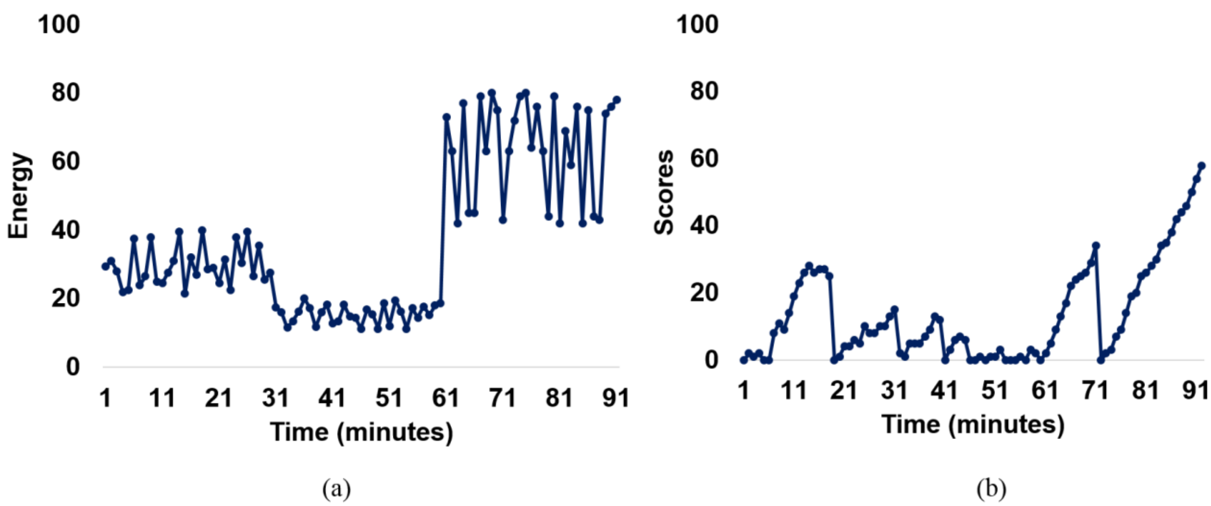


Figure 47: *Energy level distribution based on users presence in zone, (b) Scores graph - current scores in a PG during journey of a user through three different zones*

Until now, the consideration for energy is influenced just by the number of users in a zone. The total number of users in the overall city could be considered as a positive factor, leading to the addition of a global CF factor.

$$E = \alpha \times (0.8 * IP + 0.2 * AZP_x) \times (1 + (0.8 * CF_x + 0.2 * CF))$$

From the above analysis, the energy is a significant and flexible game mechanics that can be used for building more robust game design and can appropriately tune with environmental factors to complement individual performance with a collaborative and collective perspective. The simulation analysis conducted for the large-scale deployment provides an effect of serious games when the number of users increases/decrease. The information collected from Trikala tests were used for analyzing the development of gaming applications to enhance the user behavior in the public transportation services.

7.4. Usability tests of real-time games - Genova

The key motives for the usability testing of real-time games were to investigate the user acceptance of the games in the transportation sector and also to compare the real-time games with previously tested games in system architecture. The initial test of the games was conducted in Turin, where the competitions, Virtual bank, and S&L were tested, but later the system architecture was extended with two real-time games (DG and PG) to provide better playful and interactive experience for the users. The implications of the usability test will enable to understand the features involved in user acceptance and also the effectiveness of the implemented games.

The first test was performed in Turin, Italy in February 2016 and the second test was conducted in Genova, Italy (October – November 2016). The test in Turin involved 18 users, the employees of companies participating in the TEAM project (FCA - Fiat Research Center, Telecom Italia, Swarco Mizar, 5T). The test was conducted in CRF premises and to display the impact of games on competitive driver performance.

***Figure 48**: FIAT 500L - The car used for tests and demonstration of applications*

The Two FIAT 500L cars, ad-hoc equipped for the TEAM project, were used and the primary game feature for the test was focused on competition, the test was organized in a way that the two cars will compete against each other (see **Figure 48**). Both drivers will exhibit varying performances, the test users can visualize the competition scores and event analysis as a result of driver performance, and they can analyze how well the other car is performing. In Turin, the GD assessment was relied on vehicle signals (speed, longitudinal and lateral accelerations, RPM) for Competitions (see **Figure 49**).

Figure 49*: Test location in CRF campus (Turin, Italy)*

In Genova, the second test was performed to evaluate the two-real time games and the test involved 18 users, who were students/workers at the University of Genova (Age - mean: 28.2, stdev: 5.5). The user assessment results were extracted from green drive evaluator on the smartphone sensors.

The test was organized with pre/post questionnaire; the pre-test form was filled by users after a short presentation. The pre-test analysis helped to understand the user expectations and activities during travel. The games were demonstrated with the impacts of good and bad driving scenarios and users were also allowed to play the games. The tests lasted from 15 - 40 minutes by a drive from Albaro to Bocadasse in Genova (see **Figure 50**). The tests were designed to assess two dimensions of user acceptance: usefulness and satisfaction. First, the driver game was tested, where two smartphones were used, the former one with game interface and the latter one with smartphone-based vehicle signal evaluator module. The smartphone-based signal evaluator was mounted on the dashboard, and another smartphone with games was given to the users.

The users experienced the gameplay for varying driving conditions (harsh and better performances), and once the driver game is completed, the users were given a chance to play the passenger game. As, the passenger game involves more user interaction, the users explored the game scene and tried to connect the happenings of the game scene with real-world driver performance.

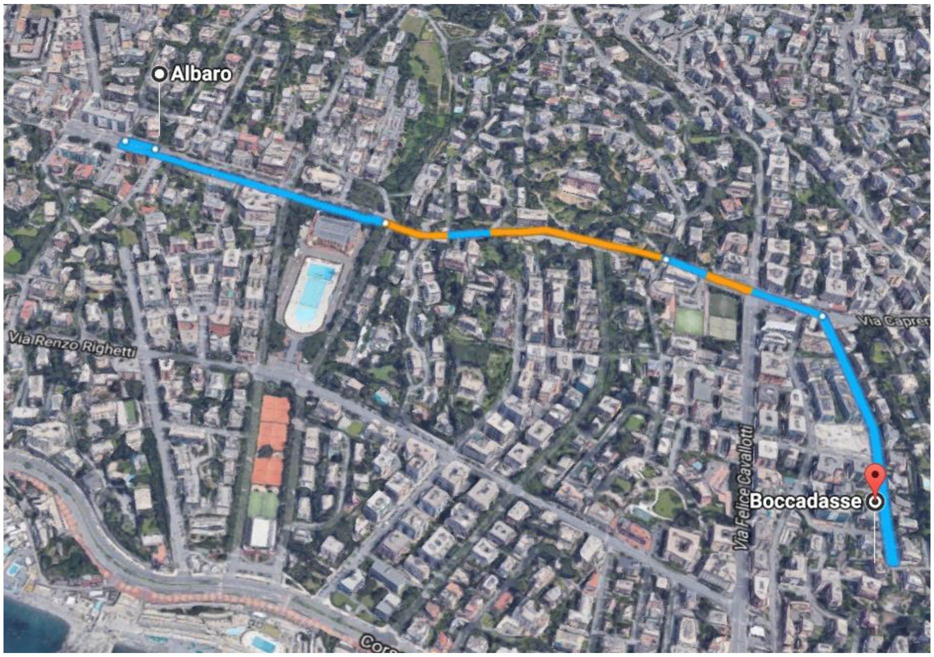


Figure 50*: Test location of real-time games in Genova, Italy*

After the tests, the users filled the post-test questionnaire and analysis was performed on the data extracted from the survey. The following section describes the analysis of both the games and comparison with results extracted from the test conducted in Turin.

The user test methodology was based on the well-established one proposed by Van der Laan [140], and the assessment for user acceptance is derived based on two dimensions: usefulness, and affective satisfaction. The Van Der Laan scale consists of nine features (1. Useful - Useless, 2. Pleasant - Unpleasant, 3. Bad - Good, 4. Effective - Superfluous, 5. Irritating-Likable, 6. Nice-Annoying, 7. Assisting-Worthless, 8. Undesirable-Desirable and 9. Raising Alertness – Sleep Inducing) with 5-point Likert and in these nine features the odd ordinal values correspond to usefulness, and even ordinal values correspond to affective satisfaction. The items 3, 5 and 8 (Bad, irritating and Undesirable) are inversed to display the outcome. Finally, the user acceptance is obtained by averaging 5 (odd values) and 4(even values) of the 9 Likert items, respectively.

The Van der Laan methodology suggests that it can be insightful first to describe the system and have the scale filled in as a before measurement, to assess ideas people have, and then again after experience with the system [140] to complete the post-test scale. Thus, the test was presented with a pre-test questionnaire with the above mentioned Likert scale features.

The post-test questionnaire comprised an extended scale for both the games - Driver Game Scale 1 (DGS1) and Passenger Game Scale 1(PGS1), focusing on gamification elements, safety, ease of use and willingness to use/buy.

7.4.1. Driver game Analysis

The pre-test questionnaire comprised 4 questions related to activities and user expectations during travel (see **Figure 51**). Most importantly, these inputs can be of reference for my analysis to correlate with outcomes and as well as it can be a reference for future research in the field of gaming in the transportation sector. At first place, the activities while traveling were listed out, such as Radio, Navigation, Alerts, and Music and from the below figures we can see that most of the users prefer smartphone for navigation purpose and the second highest number goes for radio. The second aspect was to understand the duration of the game, which they would like to play during travel and most of them prefer to play games from 10 - 20 minutes. As a major reason for gaming, the highest contribution was towards improving driver performance and however the analysis of driver performance was also a key aspect to be considered. For evaluation strategy in games, the users have opted for driver game, and comparative gameplay option was also considered as an important element. From these considerations, it can be seen that users have a preference to play games during travel for improving the performance or competing with their peers.

However, it is necessary for the future work to consider the game duration, as it should not burden the user with more requirements. When coming to major activity, while traveling the users have mentioned that they use smartphones for navigation and it seems like a passive entity, where the user just need to mount the phone on the dashboard and they get feedback from maps application.

While designing games, especially for drivers, the key point to be noted is that the game needs to be passive and should not distract the driver from the main driving task. As discussed earlier, the passive gameplay can reduce the user involvement in games and to encounter that issue a timely feedback module and real-time gaming scenario were used as a foundation for the driver game design. In future work, further properties can be provided for the users with various game strategies, and they can prefer the gameplay based on their liking, and this can give users a different experience as the monotonous gameplay can make users disengage from gaming. Even in existing architecture of SG_CB, the new games can be added up, but the driver game was the first test to ensure the deployment of games for the driver.

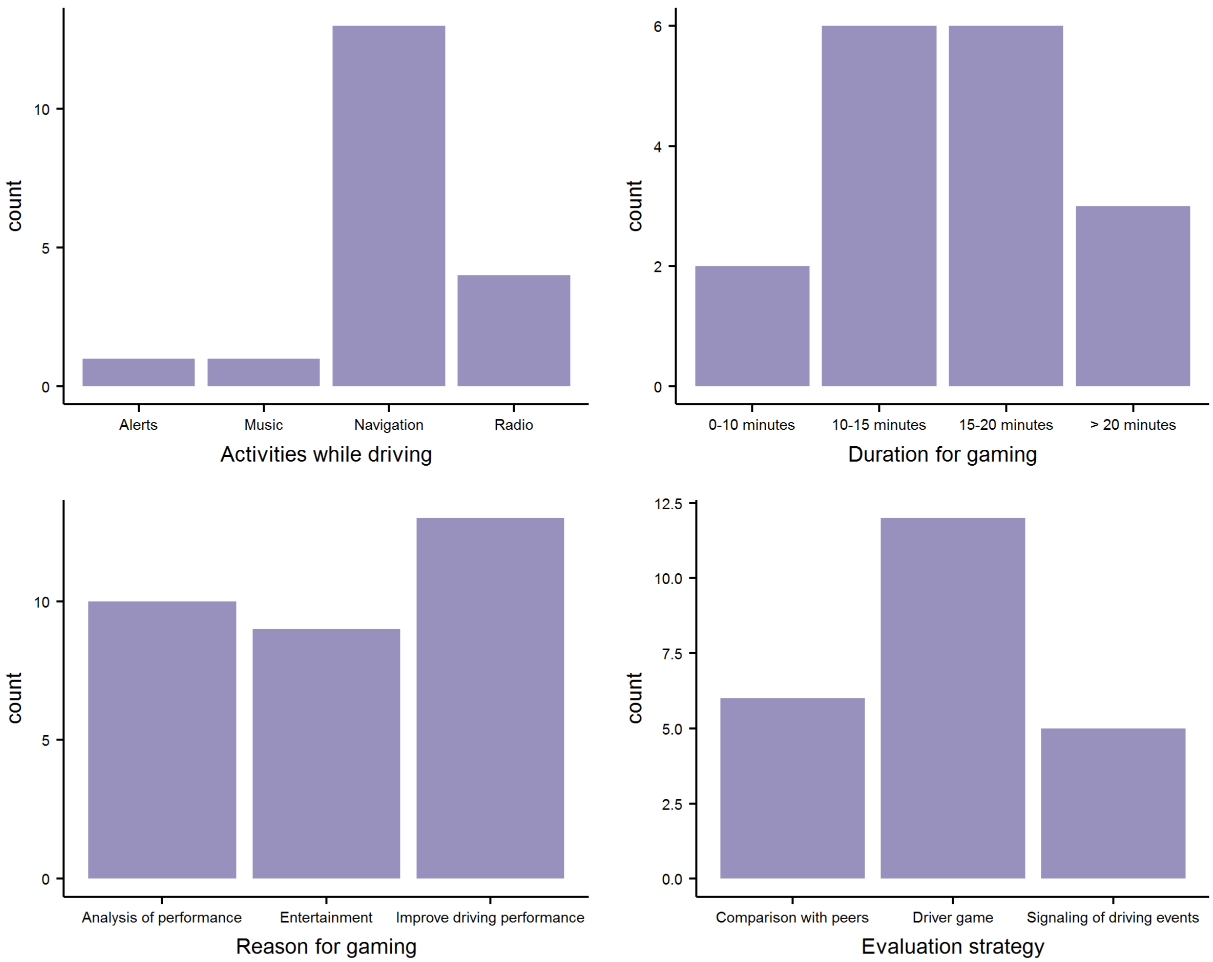


***Figure 51**: Pre-test questionnaire of driver game with main focus on user expectations while traveling*

Let's start analyzing the post-test questionnaire and the post-test questionnaire comprised of two sets, the former one corresponds to the game parameters (DGS1), and latter one corresponds to the user acceptance scale. In DGS1 scale the main focus was on the key parameters in the game such as interactivity, safety, gameplay mechanism and ease of use, the questionnaire set in DGS1 is represented in the **Table 5**. The responses were recorded on the five-point Likert scale (1-5), where 1 represents strongly disagree, and 5 represents strongly agree.

The first 4 questions (Q1-Q4) focus on game functionalities such as the association of gameplay with real-world happenings, the gameplay mechanism (rewards/downfall) and interactivity.

The questions (Q5 and Q6) focus on the safety of driver and passengers. As the measure of safety is a fundamental procedure to analyze how much safer it is to deploy games in the transportation industry.

The internal consistency of the driver game responses was tested through reliability scores from Cronbach's alpha computation (see **Table 6**). The values for all the scales stand more than the reliability coefficient 0.7, except for the satisfaction metric from pre-test (0.67), where the value was less than the reliability coefficient.

Table 5: *Post-test questionnaire for driver game with focus on game parameters and design elements*

Q1	The Driver game provides an appropriate gamified representation of driver performance
Q2	The Driver game incentivizes the driver when the performance is optimal
Q3	The bad driver performance impacts the game and a downfall happens in gameplay
Q4	The use of Bonuses and Maluses provide an immediate feedback for driver performance
Q5	The use of the game by the driver decreases safety
Q6	The use of the driver game by a passenger decreases safety

***Table 6**: Internal consistency test - Cronbach alpha score for driver game questionnaire*

Driver Game	Usefulness	Satisfied
Pre-test	0.80	0.67
Post-test	0.85	0.92
DGS1 – post-test	0.76	

From the post-test analysis of the scores (see **Figure 52**: Post-test questionnaire scores of DGS1 scale), in DGS1 scale the questions Q1 – Q4 determines the user experience in gameplay such as the strategies, energy, rewards, and downfall. The questions Q2, Q3, and Q4, have secured better acceptance rate (72% and 83%) from the users, and through this, we can interpret that the reflection of real-world behavior on the game scene is instantaneous, the immediate feedback mechanism in gameplay influences better performance. When introducing immediate feedback aspect, the passive entity in gameplay will fade, as the game connects the user on a timely basis and also prompts the user for choices to be made for progressing the gameplay. Tasks in games will emphasize the users to persevere in the state of gameplay and progression. The game mechanism can comprise of limited tasks, which users can complete, and the complexity of the tasks can be varied while the user proceeds with the game. Initially, the user involvement and progression in the game are necessary, only then the captivating gameplay mechanism can influence the user behavior. The levels in DG corresponds to limited timeframe, as each level is a task for the player. The ratings for Q1 is less compared to other responses, the Q1 corresponds to the gamified representation, and it is noted that the game dynamics can be tuned concerning duration. As the games are interfaced with the centralized cloud server, there are possibilities to expand the game architecture with more features and genres. Options can be opened for the new game developers to contribute various games for mobility, as new games can exploit the user performance details from the cloud server. By providing various types of games, there can be more users attracted to use the system.

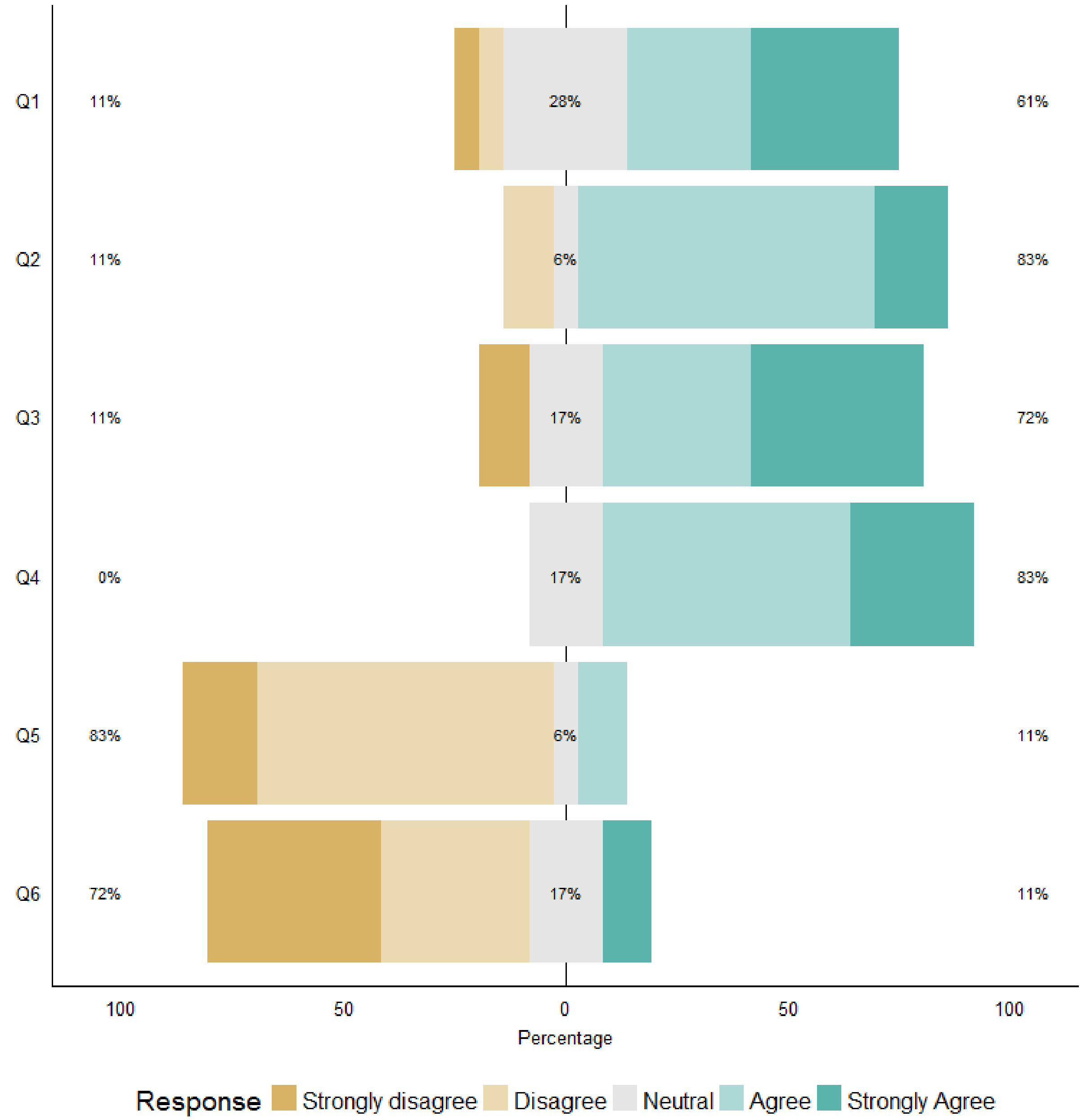


Figure 52*: Post-test questionnaire scores of DGS1 scale*

Apart from DGS1 scale, the users also marked for their willingness to use the game if freely available and to analyze the correlation between the user acceptance and willingness to use; I have plotted a correlation graph on user acceptance response Vs. Willingness to use.

Table 7: *DGS1 scale for individual questions (Q1-Q6) with mean and standard deviation in brackets. The questions Q5 and Q6 have been reverse coded to match up with rest of the values.*

User acceptance Questionnaire(DGS1)	Driver Game(Genoa)
Q1	3.7(1.1)
Q2	3.8(0.8)
Q3	3.8(1.2)
Q4	4.1(0.6)
Q5(Reverse coded)	3.3(1.0)
Q6(reverse coded)	4.2(0.5)

Table 8: *Usability dimensions assessment scores (1-5 Likert scales) – Mean and standard deviation (in parentheses) values – Pre-test*

User acceptance dimensions	Driver Game(Genoa)
Usefulness	4.1 (0.7)
Satisfaction	4.0(0.8)

From the correlation plot, it can be noted that all the features of user acceptance are positively correlated with willingness, especially the features 2, 3, 4, 5, 6 and 8 have better correlation score (> 0.7), feature 7 (0.64) and features 2 and 9 have scores less than 0.4. The even ordinal scales, which corresponds to affective satisfaction have a higher correlation with willingness. In case of usefulness scale (odd ordinal values), only two features (3 and 5) have contributed for higher correlation score.

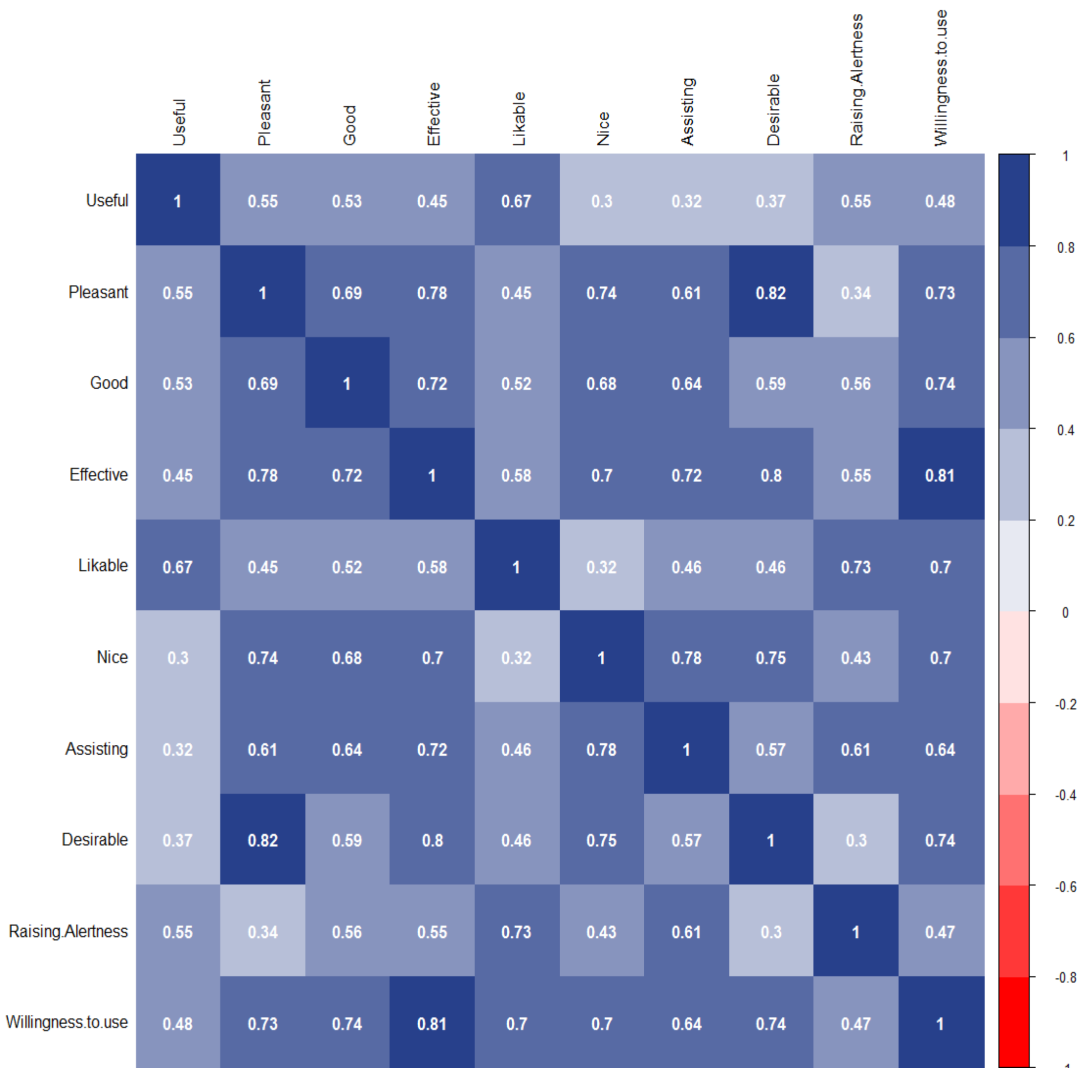


***Figure 53**: Driver game - Correlation plot of user acceptance Vs. willingness to use*

7.4.2. Passenger game Analysis

During the passenger game tests, the users were allowed to play the game and experience the game environment. The pre-test questionnaire of passenger game comprised 3 questions focusing on the activities of passengers while traveling and also the duration of gameplay, which they would prefer to have on travel (see **Figure 54**). When analyzing the pre-test questionnaire, the reason for gaming received more responses towards entertainment than analysis of driver performance. From the standpoint of a passenger, the game needs to hold more entertainment value and also there needs to be a measure to represent the analysis of driver performance. However, there was an option where users can select both reasons. Combination of entertainment and representation of analysis are to be considered during the game design phase. The responses concerning the game duration seem almost similar with slight variation in weightage compared to the driver game, where most of the users prefer to play a game ranging between 5 – 15 minutes, and there are also some responses for more than 20 minutes. So, the duration is one of the main factors that need to be considered, for example: if the game is scheduled for 20 minutes gameplay, then it needs to provide an entertainment value to the user for adapting the gameplay and also for understanding the driver performance. The entertainment value of the game can combine more playfulness and fun as these elements will motivate the users to enjoy the gameplay. In passenger game, the fun was associated with the changes in the game environment due to varying driver performance. Because the complexity of game depends on the driver performance and that can range anytime.

Finally, when considering the activities while traveling, the passengers have more options and out of which the top selections were listening music and social networking. But, playing games is also a major aspect, as it had got the second highest responses. By leveraging the social networking ability and playfulness in games- the aspect of collaborative gaming for passengers will encourage more participants. Therefore, the analysis from pre-test was taken into consideration during the first pilot test in Genova (July 2016), and they were implemented during this user tests. Key factors that were taken into consideration for the passenger game are ease of use, interactivity issues, and more playfulness in games. The analysis described here can be taken into account for future work in implementing games for the automotive domain and also for large-scale deployment, where more users will be involved.

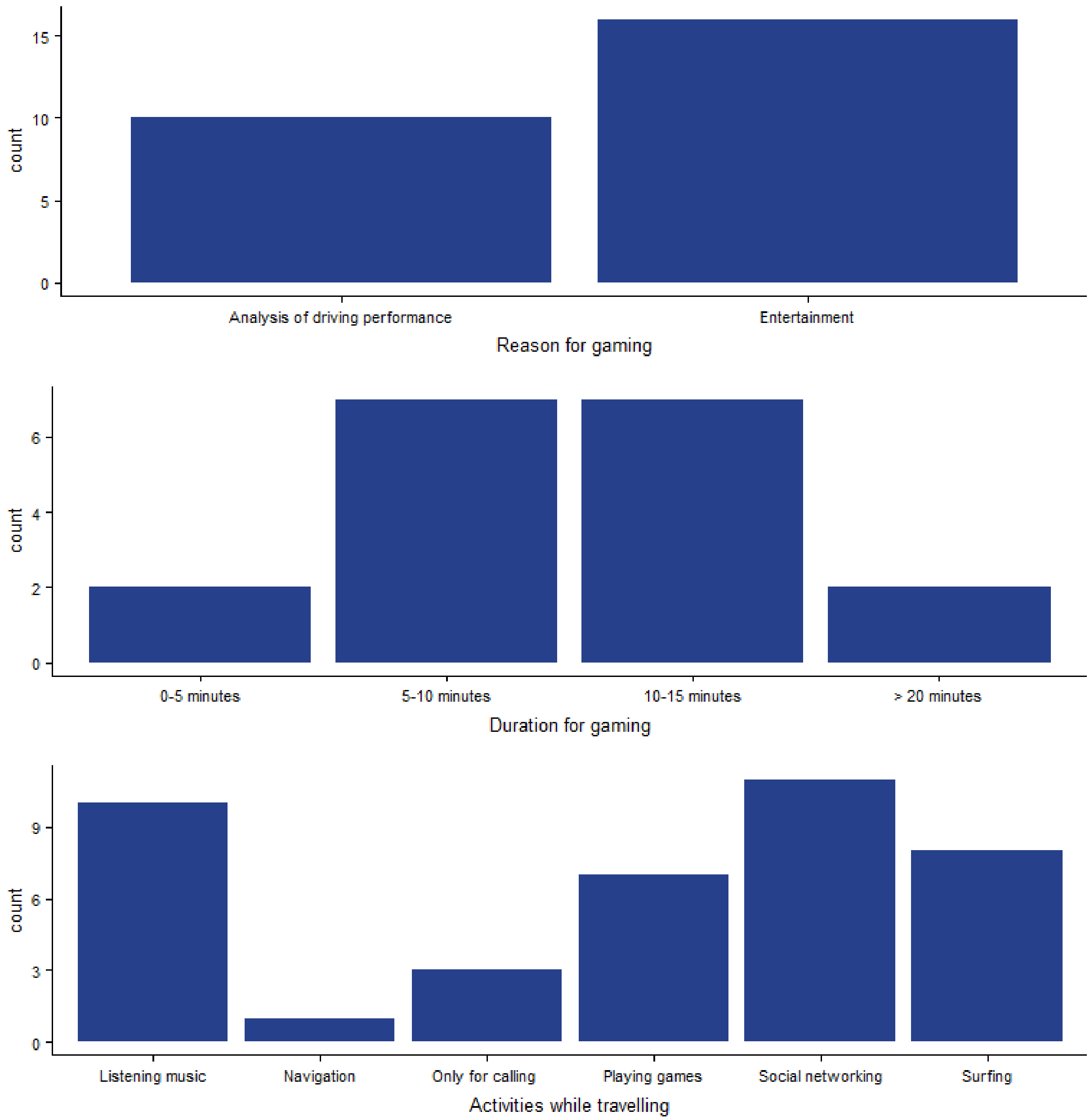


***Figure 54**: Pre-test questionnaire of passenger game with focus on user activities and preferences during travel*

In the post-test analysis, the PGS1 questionnaire was more focused on the usability, playfulness, game interface and strategy (see **Table 9**). The safety was not taken into account, as the game is developed for passengers only. The questions Q1, Q3, Q5, and Q6, corresponds to the reflection of driver performance on game scene, such as how the game is connected to the real-world happenings? and does the driver performance in real-world affects the gameplay?. Whereas questions Q2 and Q4 are more focused on playfulness and user engagement in the game. When it comes for passenger game, the fundamental aspect is that it transcends the real-world happenings in the game with immediate effects, so it is highly important that the users get to understand driver performance and also have better gaming experience.

Table 9: *Post-test questionnaire for passenger game for PGS1*

Q1	The Passenger games facilitates the passengers to understand the implications of driving behavior
Q2	The passenger game comprises of considerable user interactivity
Q3	The passenger game establishes a relation between the real-world driving activity and digital game environment
Q4	The passenger game engages the player with gameplay
Q5	The passenger game provides more scope for the player to exploit the game environment and advance the levels, when the driver performance is good.
Q6	The passenger game transforms the game environment with unfavorable happenings for the player, when the driver behavior is bad.

The internal consistency of passenger game responses was analyzed through the Cronbach alpha score and from the results we can see that all the values are greater than the reliability coefficient 0.7. The score for satisfaction is a bit higher than usefulness (see **Table 10**).

***Table 10**: Internal consistency test - Cronbach alpha score for passenger game*

Passenger Game	Usefulness	Satisfied
Pre-test	0.79	0.80
Post-test	0.89	0.87
PGS1 – post test	0.77	

The responses from PGS1 are represented in **Figure 55**, from results it can be noted that Q6, Q4, Q2 and Q5 (89%, 78%, 78% and 72%) have maximum weightage for responses compared to Q1 and Q3 (61% and 67%). The playfulness and user interactive have gained more weightage and this represents that the users were satisfied with interface and strategy. However, this can be further improved by increasing the gameplay duration with more strategy and option for the players. Because, when it comes to passenger game, the duration can be around 20-25 minutes, as short duration at times will not facilitate to capture all the driving events. In specific, it is a hard case scenario where the driver continuously exhibits harsh driving behavior in very less time. The fact of increasing gameplay can also add up value for playfulness and further stimulate users to participate in games actively.

A collaborative gameplay with more comparative aspects such as: competing with fellow passengers can be an additional entity in gameplay. Passengers traveling in two different routes can play a game, where the energy for the game can be divided into two factors with former one coming from the driver performance associated with a particular route and latter one corresponding to passenger gameplay skills.

Even though user's skill in handling the game scene varies, then the driver performance will also impact the gameplay. The element of fun can be further improved by incorporating the collaborative game designs, and this can be a consideration for the future work in this domain.

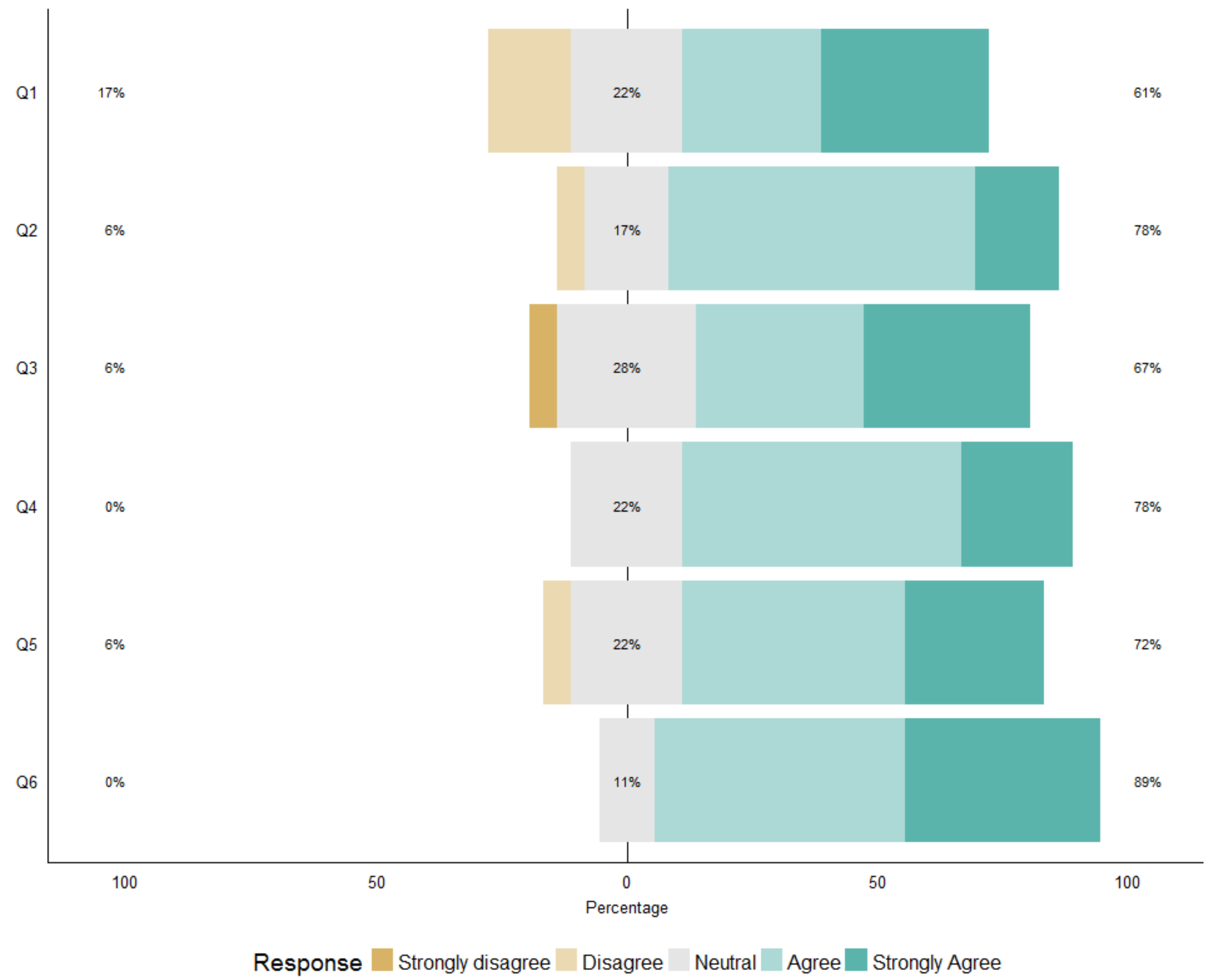


***Figure 55**: Post-test questionnaire scores of PGS1*

Similarly, the correlation analysis was conducted for passenger game with the comparison of user acceptance with a willingness to use. From the correlation graph plotted in **Figure 56**, the features 2, 3, 5, 6 and 8 have a higher positive correlation with values exceeding 0.7 and features 1, 4, 7 and 9 have a nominal positive correlation. This represents that the satisfaction aspect of user acceptance has more inclination and positive correlation towards willingness to use compared to the usefulness aspect.

Table 11: *PGS1 scale for individual questions (Q1-Q6) with mean and standard deviation in brackets.*

User acceptance Questionnaire(PGS1)	Passenger Game(Genoa)
Q1	3.7(1.1)
Q2	3.8(0.7)
Q3	3.8(1.0)
Q4	4(0.6)
Q5	3.9(0.8)
Q6	4.2(0.6)

But, considerably the correlation scores for passenger game are slightly higher than the driver game, where the results of passenger game have better correlation towards the willingness to use.

Table 12: *Usability dimensions assessment scores (1-5 Likert scales) – Mean and standard deviation (in parentheses) values – Pre- test*

User acceptance dimensions	Passenger Game(Genoa)
Usefulness	3.9(0.8)
Satisfaction	4.0(0.8)

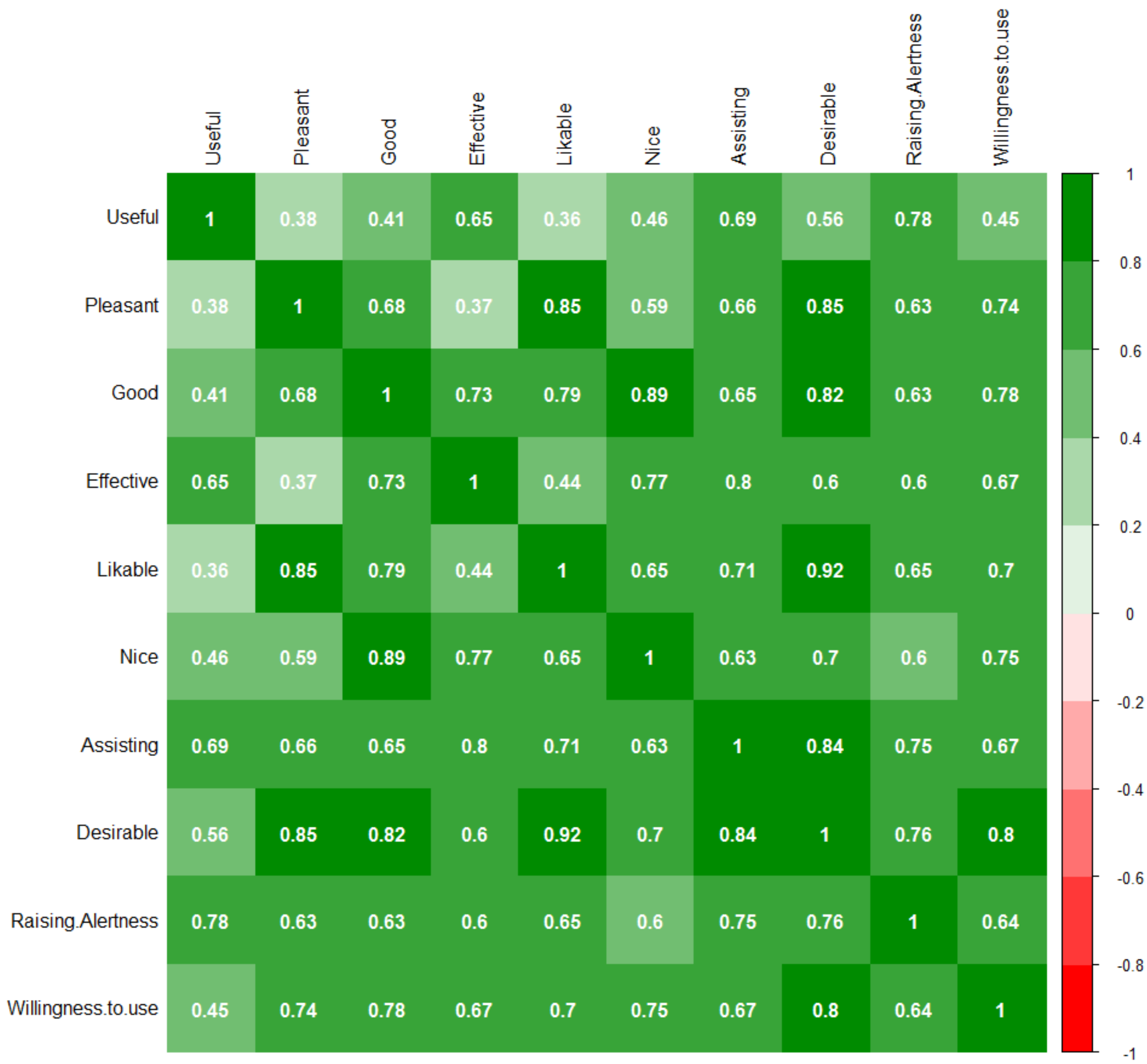


***Figure 56**: Passenger game: Correlation plot of user acceptance Vs. willingness to use*

7.4.3. Comparative study of usability tests from Turin and Genoa

The real-time games were deployed to the system architecture after the analysis of results extracted from initial tests conducted in Turin (February 2016). The specification of the tests is mentioned in the initial phase of this section. A comparative study of the user test results conducted in various test sites and different game strategies can provide more insight into user preferences. In this section, a detailed analysis of results from Turin and results of the real-time games conducted in Genoa are discussed.

Table 13: *User acceptance test specifications*

Test Site	Games tested	Aspects measured	Number of participants
Turin	Competitions, Virtual bank and S&L	Usefulness, satisfaction, safety and willingness to use	18
Genoa	Driver game and Passenger game	Usefulness, satisfaction, safety and willingness to use	18

Table 14*: Usability dimensions assessment scores (1-5 Likert scales) – Mean and standard deviation (in parentheses) values – Post test*

User acceptance dimensions	Turin	Passenger Game(Genoa)	Driver Game(Genoa)
Usefulness	3.4 (0.8)	3.8 (0.8)	4.1 (0.7)
Satisfaction	3.8 (0.7)	4.1 (0.7)	3.8 (0.9)

Table 14, shows the average post-test results for the two acceptance dimensions. According to 5% 2-sample t-tests, there is no significant difference between pre and post results, even if results of the pre-questionnaire are slightly higher. The same test shows no difference between the Passenger game and driver game results in Genoa. According to 5% 2-sample t-tests, there is no significant difference in satisfaction between Turin and Passenger game (Genoa) nor Turin and Driver game (Genoa). There is a significant difference, instead, in usefulness between Turin and Genoa (passenger and driver games) ($p < 0.01$). Normality of the samples was tested through a 5% Jarque-Bera test.

Table 15: *Usability dimensions assessment between pre and post-test evaluation of the driver and passenger games. The table comprises the p value and degrees of freedom (df)*

User acceptance dimensions	Passenger Game(Genoa)	Driver Game(Genoa)
Usefulness (Pre and post)	P=0.71, df = 34	P=1.0, df = 34
Satisfaction (Pre and post)	P=0.48, df=34	P = 0.48, df = 34

Table 16: *Usability dimensions assessment between the driver and passenger games. The table comprises the p value and degrees of freedom (df)*

User acceptance dimensions	Between Driver Game and passenger game (Genoa)
Usefulness	P=0.23, df = 34
Satisfaction	P = 0.27, df = 34

Table 17: *Usability dimensions assessment between the Turin and Genoa tests. The table comprises the p value and degrees of freedom (df)*

User acceptance dimensions	Turin/ Passenger Game(Genoa)	Turin/ Driver Game(Genoa)
Usefulness	P= 0.14, df = 34	P=0.008, df =34
Satisfaction	P=0.20, df=34	P=1.0, df = 34

***Table 18**: Median values of three Likert items concerning willingness and safety*

	Turin	Passenger Game(Genoa)	Driver Game(Genoa)
Willingness to use	4	4.5	4.5
Willingness to pay	2	2	2
Safety	4	-	4

Table 18, shows the median values of three Likert items that are not part of the Van der Laan scale [140] but are considered important for the apps and project. Results are very similar across the different conditions. According to a Wilcoxon signed rank sum test, there is a significant difference ($p < 0.01$) between willingness to use and willingness to pay in all the three cases.

Analyzing the results, we see that there is a good expectation about gaming related to driving, which is substantially confirmed by the experience. The implemented games are considered more satisfying than useful. The Driver game looks more useful than satisfying, and this represents that the game seems to address a need by drivers to improve their green driving performance. In case of passenger game, the results represent that it is more satisfying than useful and this can be stated as the passengers were more concerned on the playfulness and interactive ability of the game.

When it comes to driver game the ultimate focus was on the feedback methodology than the game interface; the game interface was crafted with more emphasis on audio feedback to avoid distraction. However, the direct and immediate feedback provided by the driver game has more value than the competition logic. Nevertheless, the performance comparisons, at least with previous drives by the same user, would be valuable, especially in a medium-long term. Willingness to pay is always significantly lower than willingness to use. The results show that users do not exclude the possibility of buying and this may be explained by the fact that most of the smartphone apps, especially games, are free or at very low cost and not comparable with any automotive accessory. From the usability studies of both the games, it is possible that the Driver game and passenger game have more potential value, especially if targeting specific users (e.g., driving school students, and analysis of individual performance).

Even certain companies can encourage their employees by monetary benefits (e.g., discount cards) to play games for green and safe mobility. The concepts can be explained to university students and can promote games for safe mobility; these games will have a positive impact by transforming the driver performance on a large scale. The games like passenger game can make other users concerning the driver to understand the impacts of driving performance. The analysis of pre-test on both the games has provided more scope for the game design and stands as a foundation for future research in the field of using games for mobility. The specific parameters that can be taken into account for the future design were listed along with the description of pre-test analysis for both games with major considerations towards duration of game and association with activities of users while traveling.

Results about safety are positive and suggest the validity of the proposed approach. In any case, safety is a major concern and should be carefully checked, for new apps that involve a very sensitive task, such as driving. Especially when designing a game for drivers, careful attention needs to be paid to designing the interface and choice of colors (it is better to avoid higher contrasts). In general, the Genoa scores are higher than Turin. Thus, the addition of two real-time games to the system architecture has a positive impact on usability tests and the games presented in Genoa tests are better.

Conclusions and future work

The potential of serious games and pervasiveness of mobile computing were exploited in this research activity to address the existing problems in the automotive domain. The initial phase of the research was focused on the literature survey to understand the problems in automotive industry, existing solutions, and their drawbacks and the key factor, which stands as a hindrance for green and safe mobility of road users. From analysis [8] [9] [10] [11] [83], it was determined that driver behavior was the basis for most of the problems associated with road safety. While analyzing the existing solutions, the systems such as ADAS, ad-hoc techniques with ML algorithms, warning, and alert systems were used to address the issue. My research aim was to incorporate the serious games mechanism into the automotive sector for tackling the issue of improving driver performance and inculcating green and safe driving behaviors.

As serious games have shown its prominence in various domains [33] [34] [35] [44] [45] [46] and the scope of research in this sector was more as the key problem of creating behavioral impact demands a solid system for coaching and motivating the users.

The use of games in automotive sector has challenges such as safety and distraction, also the incorporation of SGs in automotive and transportation sectors is new dimension concerning the games deployment, as only few research activities are carried out in this domain with more space for research and innovation in: analyzing deployment solutions, user feedback, game design parameters, real-time field tests and game typologies. The primary requirement was to form a virtuous cycle to improve user behavior through the implementation of three different game typologies, which are housed in cloud server dedicated for centralized architecture (SG_CB framework). The concept of virtual sensors was established for evaluating the user behavior and providing inputs for the games. Applications dedicated for mobility comprises a virtual sensor, and this means that each application has its own evaluation pattern (for example SG_CB assess the green drive behavior of the users and CPTO assess the user behavior in following up with the travel instructions). Even the 3rd party applications can utilize the SG_CB framework by RESTful web services and as the games deployed in the cloud server can adapt to the needs of 3rd part apps. Therefore, to address the RQ1, which concerns the design and game logic features, the evaluation pattern is a key in game design and in fact it is a foundational aspect for the games to function efficiently.

So, to design better game logic and to foster the games for improving mobility quality, it is essential to have a centralized architecture, where multiple applications (3^{rd} party apps) can also exploit the benefits that games could contribute. The centralized architecture will also fit for the context of games in transportation, as the major elements of transportation involve parking, navigation and driving.

In address to the RQ2, where the focus is on the behavioral impact and performance improvement, a better feedback module need to be established. Apart from games, a deeper insight into driver performance was needed and as a supporting factor for gamification a driver coaching module – "Event Analysis" was implemented. When the driver performance evaluator module computes the user scores, a parallel evaluation metric was introduced to capture the harsh driving events such as: high acceleration, harsh brakes, high RPM and steering wheel angle. The event analysis module focuses on the individual performance analysis, and at the end of the trip, the user gets a complete report with a timestamp, intensity of the event and representation of the events on maps. During the initial plug-in tests (conducted in Italy and Sweden), the competition and event analysis modules were tested for stabilizing the driver performance evaluator and also to analyze the various driving behaviors.

When dealing with RQ3, which emphasizes more towards the motivation factor, it is necessary to compliment the better performances exhibited by the users on various occasions. The factor of motivation enables the users in active participation and also in long-term commitment towards the gameplay. To strengthen the fact of motivation, a competitive gameplay aspect can also be included for the users to compete with their peers and to compare the individual performance with the performance of others. Both these features were added in my game logic through the virtual bank and competitions. Additionally, the rewards provided by the virtual bank can be utilized on the real-world applications.

A basic social networking option was included in the SG_CB application for the users to manage their profile, receive performance notifications and to establish information sharing in groups and on walls. These features were supplementary elements for gaming and they add value to community building were more users can collaborate and form a network for sharing game details. After the first plug-in tests, further analysis was performed to develop two real-time games for drivers and passengers, as the existing games lack the features such as immediate feedback and playfulness. The driver game was focused more on immediate feedback mechanism with non-interactive gameplay mode, and passenger game focused more on playfulness and collaborative gameplay. Then an integration test was performed to study the impact of games on public transportation systems. The CPTO application has been integrated into the SGs framework so that users can engage with the system by playing one or more games, whose outcome depends completely on the real-world performance of the user. Since the demand service is highly sensitive to the reliability of information from the user requests, the user assessment metrics currently implemented for the CPTO simply evaluates the reliability of the information provided by the user. The SGs framework involves various game typologies, with different levels of user interactivity and targeting different types of user preferences. The app was successfully tested in Trikala (Greece), the data about gameplay was collected and later used for a larger scale deployment simulation, where a structure of energy was proposed - for a game mechanic that seems particularly suited to account the values coming from the real world - comprising other parameters(crowd factor and average zone performance and) beyond individual user performance.

The integrated system of SG_CB and CPTO was a simple example of applying SGs to real-world mobility systems. The concept of SGs in transportation can be extended in future with more gaming options, as the architecture is designed for extensibility. The use of established game concepts (e.g., Pac-Man, Tetris) may be appealing to users while keeping short the time in which the users must acquaint with gameplay. Finally, game rewards associated with real-world should be able to give more scope to extend the collaboration with public authorities, retail outlets and online shopping portals for providing benefits for the users. It is an opportunity for public authorities and other outlets to be a part of this ecosystem to foster collaborative and optimized transportation. The results from workshop and field test scenarios concerning the game deployment looks particularly suited to support vehicle manufacturers, customer loyalty programs and to promote new mobility services (e.g., by municipalities) [142] [143].

The real-time games (DG and PG) were tested on public buses and various drive sessions in Genova to ensure that gaming parameters reflect towards the real-world happenings. The RQ4 was also evaluated in the real-time games during the field tests and usability study conducted in Turin and Genoa. The challenges associated with the real-time games such as configurational issues, design issues and game parameters tuning were resolved by analyzing the game outcomes from the field tests and pilot test with few users. Several observational studies were conducted on these two games, with ranging driver behaviors, different vehicles, comparative performance analysis and simulation for large-scale deployment. Finally, the user acceptance of the games tested in Genova was good compared to the earlier games deployed in Turin and other test sites. The user acceptance for these games was measured on the two dimensions of user acceptance, which are the usefulness and affective satisfaction. From, the results it is more evident that the games were more satisfying and comprised a positive correlation with willingness to use. The user study provided other useful aspects such as the considerations for game design elements and user preferences for games in automation. Future work can focus more on collaborative gameplay in both driver and passenger games, as the current implementation focuses more on individual user performance. Including more collaborative aspects can add up fun and playfulness. To increase more collaborative gameplay features in passenger game, an additional entity called "*competitive driver score (CDS)*" can be plugged into the energy equation that was devised for passenger game.

$$E_p = IP_p + (0.3 * DP_p + 0.2 * CDS_p)$$

The CDS of a passenger can be derived by computing the percentile score of the driver performance corresponding to the peers in a zone. By including this feature, the effect of driver performance in the zone will be taken into consideration. So, the performance of other drivers will also impact the energy factor of the passenger. The weightage of contribution to the total energy can be tuned accordingly, therefore more collaborative features can be plugged into energy equation for increasing the playfulness and fun in the PG. The logic of energy can be exploited in new games as well, where the concept remains same but the game strategy can evolve and reflect the outcome of energy factor.

The game strategies can comprise of well-established concepts as the acquaintance with gameplay becomes more convenient and familiar for the users. The configurational settings like connection setup and other background process should be addressed during the initial stages, and the process of launching games and supplementary procedures should be convenient for the users.

More usability tests can be performed on the integration of 3rd party applications to SGs framework, and the tests can focus on user preferences concerning the game design, game parameters, usefulness of tool and acceptance ratio. However, the user study in transportation domain for various applications are expensive (concerning the apparatus setup and modules) and time consuming. The incentive schemes for users can be provided with certain benefits (online retail and discount vouchers) to encourage them in participating for the user studies. From a technical viewpoint, the feedback from the tests will be useful for the future design and development. Also, the investigation carried out in deployment factors will entice further research in developing new kinds of collaborative mobility applications, real-time games, user behavior gamification, exploiting the diffusion of vehicles, connectivity and human collaboration with a view to achieve better mobility through SGs.

Thus, the potential factors of serious games can be used to motivate the users to take part in gaming session and improve the behavior and choices associated with the real-world scenarios. The outcomes from the deployment of SGs in automotive and transportation sectors can create a performance improvement and enable the green and safe driving behaviors in road users.

Findings and highlights

- *The first aspect is, the incentives create motivation and enable the users to maintain an optimal behavior at most of the instances. The aim was to improvise the driver performance and cultivate the green driving traits, but it is more important to facilitate the users to persevere in the state of betterment and keep improvising tenaciously. The rewards and incentives can motivate the users to proceed with the gameplay and this point adds up to RQ3.*

- *The competitive strategy uplifts the performance of user and peers associated in a competition and especially, the strategy is the core of gaming applications and inducing a concept through strategy works well in reaching the audience, as it is transmitted through an engaging medium. The RQ2 and RQ are emphasized in this point.*

- *The post-drive event analysis of driving pattern increases the causal understanding of users (the relationship between cause and effect), and this can supply more knowledge about the process and further facilitate in developing green driving behavior. The event-analysis focuses more towards the feedback aspect and thus it contributes to the RQ2 for behavioral impact and performance improvement.*

- *The Collaborative framework and information sharing (messages, performance reports, etc.) among the road users, promote the networking abilities and this aspect can be used to create awareness and prevent the disorders and chaos in the road.*

- *The immediate feedback impacts the driver performance and intimates the driver regarding the performance on a timely basis. The driver gets an understanding of harsh maneuvers and tends to rectify them.*

- *Performance gamification is another major aspect to provide a solid visual feedback. The process of gamification encourages the user to maintain optimal driving behavior. In collaborative gameplay (more users competing in one game) mechanism, more users tend to participate and exhibit their performance, and this mechanism uplifts the green driving performance of road users.*

- *The centralized architecture with generalizable game designs can enable more applications to utilize the game concepts and deploying a familiar game logic (e.g., PacMan or Tetris) can significantly reduce the time in which users can acquaint with the gameplay. The design aspects are key considerations for developing games in transportation sector and the concept of centralized architecture addresses the RQ1.*

- *Including a collaborative gameplay can increase playfulness and fun, such as the factors affecting game can be decided by user skills in-game world and user choices in the real-world. Thus, designing games to coordinate with real-world applications can match up with user expectations.*

- *Design and aesthetics are the key concern for developing games for drivers because it is a more sensitive issue and holds major importance than the game design. The game scene should not have any distractive objects, and the interaction of the game can happen only when the vehicle stops. The simpler design with status feedback through audio can reduce visual distraction.*

- *The energy is a significant and flexible game attribute that can be used for building more robust game design and can appropriately tune with environmental factors to complement individual performance with a collaborative and collective perspective.*

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Research Planning and workflow schedule – A Gantt chart report

PhD Research Activity - CycleXXX (2014 - 2017)

Oct 31, 2017

Elios Lab- University of Genoa

Project dates	Nov 3, 2014 - Nov 1, 2017
Completion	99%
Tasks	124
Resources	1

The research activities and tasks associated with Ph.D course. The precise timeframe representation of all the activities that were carried out.

PhD Research Activity - CycleXXX (2014 - 2017)

Oct 31, 2017

2

Tasks

Name	Begin date	End date
Analysis of Gamification models	11/3/14	11/24/14
Study on State-of-Art	11/3/14	11/14/14
Documentation of findings	11/17/14	11/24/14
Vehicle Signal Processing	12/3/14	2/6/15
Revision work on Java Concepts	12/3/14	12/5/14
Management of timers for vehicle signals	12/8/14	12/19/14
Deployment on OSGi environment	12/22/14	2/6/15
Study of OSGi framework	12/22/14	12/23/14
Conversion of Java projects into OSGi standards	1/7/15	1/9/15
Deployment test of Vehicle signals on OSGi framework	1/12/15	2/6/15
Driver Behavior Analysis	2/9/15	6/18/15
Study of Machine Learning algorithms	2/9/15	2/18/15
Implementation of Kohonen Neural Networks and tests	2/18/15	2/27/15
Integration of Kohonen Neural Networks to System Architecture	3/2/15	3/10/15
Component testing of Neural Networks Module	3/11/15	3/20/15
Updations and fixes	3/23/15	3/27/15
Testing with updated vehicle signal patterns	3/30/15	4/6/15
Study of Naive Bayes Classifier(Supervised Learning Approach)	4/7/15	4/14/15
Implementation of Naive Bayes Classifier	4/15/15	4/24/15
Report preparation for ApplePies Conference	4/21/15	4/27/15
Final tests and implications	4/27/15	5/1/15
Mapping relativity of Vehicular signals	5/4/15	5/14/15
Integration of Naive Bayes classifier to system architecture	5/15/15	5/22/15
Comparison of Naive Bayes with test drive data	5/25/15	5/29/15
Poster preparation for GE2015(Siena) Conference	6/1/15	6/3/15
Culmination of results of Evaluators developed	6/4/15	6/18/15
Integration of Google Maps	6/22/15	7/31/15
Study of Android basics	6/22/15	6/26/15
Installation and configuration of Environment	6/29/15	6/30/15
Study of Google Maps(Android)	7/1/15	7/8/15
Development of Driver coaching Module	7/9/15	7/31/15
Map representation of Driver coaching details	7/9/15	7/17/15
Development of Collaborative map application(template)	7/20/15	7/31/15
Culmination of Driver Coaching module	9/1/15	10/2/15
Integration of driver coaching module(Map representation) in system architecture	9/1/15	9/10/15

PhD Research Activity - CycleXXX (2014 - 2017)

Oct 31, 2017

3

Tasks

Name	Begin date	End date
Preparation for lab tests	9/25/15	10/2/15
Simulation Test and Analysis of Real-time gaming	10/5/15	12/3/15
Implementation of Bluetooth module on smartphone Application(Game Prototype -1)	10/5/15	10/12/15
Managed the functionalities for Live user performance analysis	10/12/15	10/14/15
Developmental plan for UI	10/15/15	10/16/15
Implementation of UI and game parameters for simulation test	10/19/15	10/26/15
Lab tests and integration of Bluetooth module with vehicle simulation unit	10/27/15	11/4/15
Connection with Aggregation server and performance test of the system	11/5/15	11/10/15
Integration of Google maps API with smartphone application	11/11/15	11/13/15
Simulation test and analysis of real-time game	11/16/15	11/23/15
Wrapping up simulation and extraction of results	11/24/15	11/27/15
Preparation and submission for GALA Conference - 2015	11/16/15	12/3/15
Development of Game prototype - 2	12/4/15	1/18/16
Game Interface Design	12/4/15	12/16/15
Consolidation of Game Design	1/14/16	1/18/16
Plug-in Test 1 - Gothenburg,Sweden	1/19/16	1/29/16
Prepared the modules for deployment	1/19/16	1/20/16
Lab tests and simulation analysis	1/21/16	1/22/16
Workshop test and integration of SG_CB module with FOKUS team,Germany	1/25/16	1/25/16
Field tests and deployment analysis in Gothenburg	1/26/16	1/29/16
Plug-in test review	2/1/16	2/12/16
Elimination of Bugs and Glitches in application	2/1/16	2/5/16
Preparation and simulation test for Euro-Eco challenge(Plug-in test 2)	2/8/16	2/12/16
Euro-Eco Challenge (Plug-in test 2)	2/15/16	2/19/16
Usability testing of TEAM application and SG_CB demo	2/15/16	2/19/16
Coursework and modifications of the SG_CB application	2/22/16	3/29/16
Modifications and upgradations from the feedback of Plug-in test 2	2/22/16	2/29/16
Responsive website design - Course	3/4/16	3/14/16
Cognitive Neuroscience and Robotics Course - EDx	3/4/16	3/14/16
Implementation of Animation scenes and alteration of	3/16/16	3/29/16

PhD Research Activity - CycleXXX (2014 - 2017)

Oct 31, 2017

4

Tasks

Name	Begin date	End date
Groundwork and prepartion for Journal	3/30/16	5/6/16
State-of-art survey and documentation	3/30/16	4/8/16
Consolidated the results and performed analysis on the outcomes	4/11/16	4/20/16
Drafted the base manuscript and revised the content	4/21/16	5/6/16
Coursework and Game Prototype - 3 implementation	5/9/16	7/6/16
Completed the programming C# and Machine Learning Courses	5/9/16	5/20/16
Started work on mobile game development for passenger based game	5/23/16	5/25/16
Studied Cocosharp framework for 2D game development in Xamarin	5/26/16	6/6/16
Created the game scene and initial structure	6/7/16	6/10/16
Deployment of game levels and parameters	6/13/16	6/20/16
Integration of passenger game to Cloud server	6/21/16	6/22/16
Completion of Passenger game	6/23/16	6/24/16
Chaning base design and implementation of refinements to driver game (Improvements from game prototype-2)	6/27/16	7/6/16
Field test of real-time games in public buses	6/2/16	7/29/16
Parameter tuning and real-time tests of the developed games	7/11/16	7/19/16
Preparation of manuscript for GALA 2016 and APPLEPIES 2016 conferences	6/2/16	7/15/16
Pilot test of games with 10 users	7/20/16	7/20/16
Updations and refinements of the system based on the field test results	7/21/16	7/29/16
ApplePies - 2016 conference - Presentation	9/1/16	9/16/16
Passenger game - upgradations	9/1/16	9/12/16
Preparation for Applepies conference 2016	9/16/16	9/16/16
TEAM Project final demo	9/19/16	11/7/16
Preparation for TEAM demo - Troubleshooting SG_CB app	9/19/16	10/12/16
Travel to Turin CRF for video making of Apps and tests	10/13/16	10/13/16
Preparation for video making and field test in Genova for SG_CB application	10/14/16	11/2/16
Preliminary analysis of Games with test users	11/3/16	11/7/16
Usability tests and Journal - special issue collaboration	10/21/16	1/27/17
usability study with multiple test users	10/21/16	11/9/16
Preparation for IEEE ITS special issue	11/7/16	11/7/16
Collaboration with Greek Partners for manuscript	11/8/16	11/15/16

PhD Research Activity - CycleXXX (2014 - 2017)

Oct 31, 2017

5

Tasks

Name	Begin date	End date
State-of-art analysis for collaborative applications(groundwork for IEEE ITS on TEAM applications)	11/11/16	11/18/16
Collaboration with Objective software for IEEE Intelligent vehicles Symposium	12/16/16	1/27/17
Statistical analysis on usability study	11/23/16	12/12/16
Final consolidation and manuscript submission in IEEE Intelligent Transportation Systems	11/21/16	11/25/16
Study of statistical analysis software R for data processing and Visualization	11/7/16	11/18/16
Finalized the statistical report and findings from usability tests	11/28/16	12/13/16
Manuscript preparation for IV 2017 and Social IoT workshop	1/9/17	2/17/17
Initial study and organization for conference submission IV 2017	1/9/17	1/20/17
Troubleshooted problems with passenger game	1/10/17	1/16/17
Submitted the manuscript to IV 2017 Commitee	1/30/17	1/30/17
Preparation of manuscript for Interacting with computers Journal	2/1/17	2/9/17
Preparation of position paper for "Designing the Social IoT" workshop in Denver	2/10/17	2/17/17
Reviews and analysis for IEEE ITS papers	2/20/17	3/23/17
Analyzed the reviews for IEEE ITS CPTO - SGCB application	2/20/17	3/23/17
Analyzed the reviews for Intelligent Vechicles symposium 2017	2/23/17	3/2/17
Collaborative Gaming concept for Public transport optimization	3/10/17	4/28/17
Devised the collaborative gameplay mechanism for CPTO application	3/10/17	4/20/17
Simulation and lab tests for CPTO application	4/13/17	4/21/17
Submitted the responses and madified the manuscript of IEEE ITS CPTO-SGCB	4/25/17	4/28/17
Case-study on Crossplatform application development	5/1/17	6/30/17
Cross platform application development on Xamarin	5/1/17	5/11/17
iOS foundations through Object C course	5/12/17	6/27/17
Attended Logic in Computer science conference (LICS 2017)	6/19/17	6/23/17
Attended Applied Game Design and Development Workshop	6/26/17	6/30/17
Data processing and analysis of usability results	7/3/17	7/19/17

PhD Research Activity - CycleXXX (2014 - 2017)

Tasks

Name	Begin date	End date
Consolidation of results and preparation for Ph.D thesis and assessment report	9/11/17	10/31/17

PhD Research Activity - CycleXXX (2014 - 2017)

Resources

Name	Default role
Pratheep Kumar	PhD Student

Entire workflow snapshot from Gantt Chart

Name	Begin date	End date
Analysis of Gamification models	11/3/14	11/24/14
Study on State-of-Art	11/3/14	11/14/14
Documentation of findings	11/17/14	11/24/14
Vehicle Signal Processing	12/3/14	2/6/15
Revision work on Java Concepts	12/3/14	12/5/14
Management of timers for vehicle signals	12/8/14	12/19/14
Deployment on OSGi environment	12/22/14	2/6/15
Study of OSGi framework	12/22/14	12/23/14
Conversion of Java projects into OSGi standards	1/7/15	1/9/15
Deployment test of Vehicle signals on OSGi framework	1/12/15	2/6/15
Driver Behavior Analysis	2/9/15	6/18/15
Study of Machine Learning algorithms	2/9/15	2/18/15
Implementation of Kohonen Neural Networks and tests	2/18/15	2/27/15
Integration of Kohonen Neural Networks to System Architect...	3/2/15	3/10/15
Component testing of Neural Networks Module	3/11/15	3/20/15
Updations and fixes	3/23/15	3/27/15
Testing with updated vehicle signal patterns	3/30/15	4/6/15
Study of Naive Bayes Classifier(Supervised Learning Approach)	4/7/15	4/14/15
Implementation of Naive Bayes Classifier	4/15/15	4/24/15
Report preparation for ApplePies Conference	4/21/15	4/27/15
Final tests and implications	4/27/15	5/1/15
Mapping relativity of Vehicular signals	5/4/15	5/14/15
Integration of Naive Bayes classifier to system architecture	5/15/15	5/22/15
Comparison of Naive Bayes with test drive data	5/25/15	5/29/15
Poster preparation for GE2015(Siena) Conference	6/1/15	6/3/15
Culmination of results of Evaluators developed	6/4/15	6/18/15
Integration of Google Maps	6/22/15	7/31/15
Study of Android basics	6/22/15	6/26/15
Installation and configuration of Environment	6/29/15	6/30/15
Study of Google Maps(Android)	7/1/15	7/8/15
Development of Driver coaching Module	7/9/15	7/31/15
Map representation of Driver coaching details	7/9/15	7/17/15
Development of Collaborative map application(template)	7/20/15	7/31/15
Culmination of Driver Coaching module	9/1/15	10/2/15
Integration of driver coaching module(Map representation) in...9/1/15		9/10/15
Integration of Collaborative map application to system archite...	9/11/15	9/25/15
Preparation for lab tests	9/25/15	10/2/15
Simulation Test and Analysis of Real-time gaming	10/5/15	12/3/15
Implementation of Bluetooth module on smartphone Applicat...10/5/15		10/12/15
Managed the functionalities for Live user performance analysis	10/12/15	10/14/15
Developmental plan for UI	10/15/15	10/16/15
Implementation of UI and game parameters for simulation test	10/19/15	10/26/15
Lab tests and integration of Bluetooth module with vehicle si...	10/27/15	11/4/15
Connection with Aggregation server and performance test of ...	11/5/15	11/10/15
Integration of Google maps API with smartphone application	11/11/15	11/13/15
Simulation test and analysis of real-time game	11/16/15	11/23/15
Wrapping up simulation and extraction of results	11/24/15	11/27/15
Preparation and submission for GALA Conference - 2015	11/16/15	12/3/15
Development of Game prototype - 2	12/4/15	1/18/16
Game Interface Design	12/4/15	12/16/15
Consolidation of Game Design	1/14/16	1/18/16
Plug-in Test 1 - Gothenburg,Sweden	1/19/16	1/29/16
Prepared the modules for deployment	1/19/16	1/20/16
Lab tests and simulation analysis	1/21/16	1/22/16
Workshop test and integration of SG_CB module with FOKUS t..1/25/16		1/25/16
Field tests and deployment analysis in Gothenburg	1/26/16	1/29/16
Plug-in test review	2/1/16	2/12/16
Elimination of Bugs and Glitches in application	2/1/16	2/5/16
Preparation and simulation test for Euro-Eco challenge(Plug-i...	2/8/16	2/12/16
Euro-Eco Challenge (Plug-in test 2)	2/15/16	2/19/16
Usability testing of TEAM application and SG_CB demo	2/15/16	2/19/16
Coursework and modifications of the SG CB application	2/22/16	3/29/16
Modifications and upgradations from the feedback of Plug-in...	2/22/16	2/29/16
Responsive website design - Course	3/4/16	3/14/16
Cognitive Neuroscience and Robotics Course - EDx	3/4/16	3/14/16
Implementation of Animation scenes and alteration of Game ...	3/16/16	3/29/16
Groundwork and prepartion for Journal	3/30/16	5/6/16
State-of-art survey and documentation	3/30/16	4/8/16
Consolidated the results and performed analysis on the outco...4/11/16		4/20/16
Drafted the base manuscript and revised the content	4/21/16	5/6/16
Coursework and Game Prototype - 3 implementation	5/9/16	7/6/16
Completed the programming C# and Machine Learning Cours...	5/9/16	5/20/16
Started work on mobile game development for passenger bas...5/23/16		5/25/16
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usability study with multiple test users	10/21/16	11/9/16
Preparation for IEEE ITS special issue	11/7/16	11/7/16
Collaboration with Greek Partners for manuscript preparation	11/8/16	11/15/16
Analyzed the outcomes of SG-CB in Trikala	11/14/16	11/18/16
State-of-art analysis for collaborative applications(groundwor...	11/11/16	11/18/16
Collaboration with Objective software for IEEE Intelligent vehi...	12/16/16	1/27/17
Statistical analysis on usability study	11/23/16	12/12/16
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Study of statistical analysis software R for data processing and...	11/7/16	11/18/16
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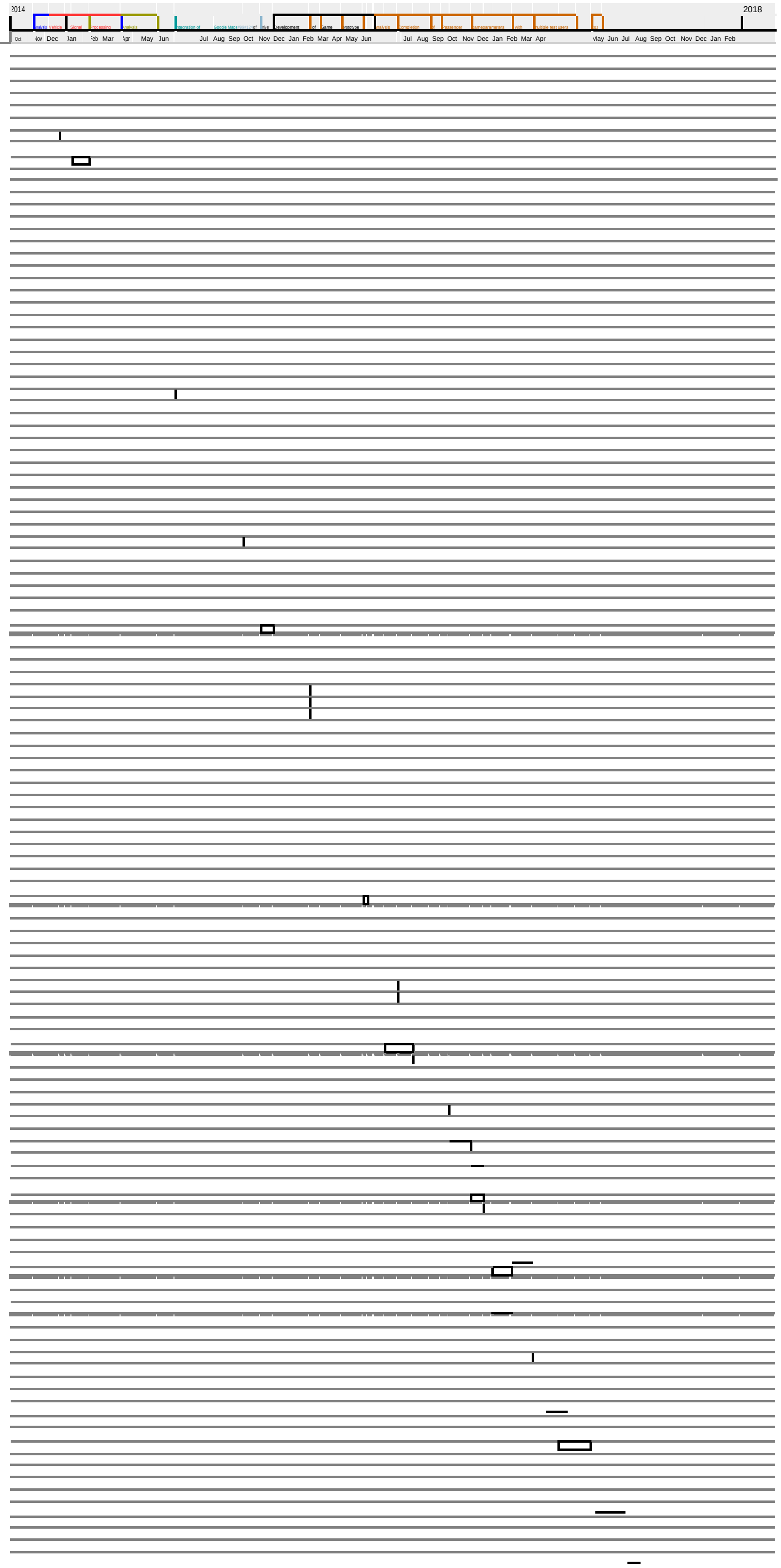
Data processing and analysis of usability results	7/3/17	7/19/17
Gathered the pilot test data and processed the results	7/3/17	7/19/17
Consolidation of results and preparation for Ph.D thesis and asses..	9/11/17	10/31/17



Appendix

Usability test questionnaire

Serious Games and Community Building (SG-CB) - Survey Questionnaire

(All the information collected will be used solely for research purpose and no individual answer linked to a person will be published)

Name:

Surname:

Sex (M, F):

Age:

Profession (Doctor, Employee, Engineer, Teacher, Student, Other):

Pre-Test Questionnaire for Driver Game

1. For which of the following activities do you use your smartphone while driving?

   ☐Navigation

   ☐Radio

   ☐Alerts

   ☐Others (please specify)

2. How long would you expect to game, while in journey?

   ☐0 - 10 minutes

   ☐10 - 15 minutes

   ☐15 - 20 minutes

   ☐20 - 25 minutes

   ☐More than 25 minutes

3. What could be the primary reason for playing a Driver game?

☐Analysis of driving performance

☐Improve driver performance

☐Entertainment

☐All of the above

4. What kind of evaluation strategy would you prefer for driving analysis?

☐The driver game (this one)

☐Comparison with peers (numeric comparison)

☐Signaling of driving events

☐Others (Please specify)

5. I would find the application to be?

(Provided the experimenter has explained the functionality of the application. Before the test we would like to hear about your expectations about this application)

Useful	|__|__|__|__|__|	Useless
Pleasant	|__|__|__|__|__|	Unpleasant
Bad	|__|__|__|__|__|	Good
Effective	|__|__|__|__|__|	Superfluous
Irritating	|__|__|__|__|__|	Likeable
Nice	|__|__|__|__|__|	Annoying

Assisting	|__|__|__|__|__|	Worthless
Undesirable	|__|__|__|__|__|	Desirable
Raising Alertness	|__|__|__|__|__|	Sleep Inducing

6. I would be willing to use the game if freely available

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

7. I would be willing to pay for the game

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

Pre-Test Questionnaire for Passenger Game

1. For which of the following activities do you use your smartphone while travelling?(as a passenger)

☐Listening music

☐Playing games

☐Social networking

☐Surfing

☐Only for calling

☐Others (please specify)

2. What could be the primary reason for playing a passenger game?

   ☐Analysis of driving performance

   ☐Entertainment

   ☐Both a & b

   ☐Others (please specify)

3. How long would you expect to game, while in journey?

   ☐0 - 5 minutes

   ☐5 - 10 minutes

   ☐10 - 15 minutes

   ☐15 - 20 minutes

   ☐More than 20 minutes

4. I would find the application to be?

(Provided the experimenter has explained the functionality of the application. Before the test we would like to hear about your expectations about this application)

Useful	|__|__|__|__|__|	Useless
Pleasant	|__|__|__|__|__|	Unpleasant
Bad	|__|__|__|__|__|	Good
Effective	|__|__|__|__|__|	Superfluous

Irritating	|__|__|__|__|__|	Likeable
Nice	|__|__|__|__|__|	Annoying
Assisting	|__|__|__|__|__|	Worthless
Undesirable	|__|__|__|__|__|	Desirable
Raising Alertness	|__|__|__|__|__|	Sleep Inducing

5. I would be willing to use the game if freely available

Strongly Disagree |__|__|__|__|__| Strongly Agree

6. I would be willing to pay for the game

Strongly Disagree |__|__|__|__|__| Strongly Agree

Post-Test questionnaire for Driver game

1. The Driver game provides an appropriate gamified representation of driver performance

Strongly Disagree |__|__|__|__|__| Strongly Agree

2. The Driver game incentivizes the driver when the performance is optimal

Strongly Disagree |__|__|__|__|__| Strongly Agree

3. The bad driver performance impacts the game and a downfall happens in gameplay

Strongly Disagree |__|__|__|__|__| Strongly Agree

4. The use of Bonuses and Maluses provide an immediate feedback for driver performance

Strongly Disagree |__|__|__|__|__| Strongly Agree

5. The use of the game by the driver decreases safety

Strongly Disagree |__|__|__|__|__| Strongly Agree

6. The use of the driver game by a passenger decreases safety

Strongly Disagree |__|__|__|__|__| Strongly Agree

7. How would you assess the overall effectiveness of the driver game?

   (Please tick a box on every line)

Useful |__|__|__|__|__| Useless

Pleasant |__|__|__|__|__| Unpleasant

Bad |__|__|__|__|__| Good

Effective |__|__|__|__|__| Superfluous

Irritating |__|__|__|__|__| Likeable

Nice	|__|__|__|__|__|	Annoying
Assisting	|__|__|__|__|__|	Worthless
Undesirable	|__|__|__|__|__|	Desirable
Raising Alertness	|__|__|__|__|__|	Sleep Inducing

8. I would be willing to use the game if freely available

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

9. I would be willing to pay for the game

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

Post-Test questionnaire for passenger game

1. The passenger game facilitate the passengers to understand the implications of driving behavior

Strongly Disagree |__|__|__|__|__| Strongly Agree

2. The passenger game comprises of considerable user interactivity

Strongly Disagree |__|__|__|__|__| Strongly Agree

3. The passenger game establishes a relation between the real-world driving activity and digital game environment.

Strongly Disagree |__|__|__|__|__| Strongly Agree

4. The passenger game engages the player with gameplay

Strongly Disagree |__|__|__|__|__| Strongly Agree

5. The passenger game provides more scope for the player to exploit the game environment and advance the levels, when the driver performance is good.

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

6. The passenger game transforms the game environment with unfavorable happenings for the player, when the driver behavior is bad.

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

7. How would you assess the overall effectiveness of the passenger game?
   (Please tick a box on every line)

Useful	|__|__|__|__|__|	Useless
Pleasant	|__|__|__|__|__|	Unpleasant
Bad	|__|__|__|__|__|	Good
Effective	|__|__|__|__|__|	Superfluous
Irritating	|__|__|__|__|__|	Likeable
Nice	|__|__|__|__|__|	Annoying
Assisting	|__|__|__|__|__|	Worthless
Undesirable	|__|__|__|__|__|	Desirable
Raising Alertness	|__|__|__|__|__|	Sleep Inducing

8. I would be willing to use the game if freely available

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

9. I would be willing to pay for the game

Strongly Disagree	|__|__|__|__|__|	Strongly Agree

Demonstration and video links

Driver game – Field test 1 (conducted in public bus in Genova) :

https://www.dropbox.com/s/g1ei2kqrggv9ezi/DriverGame.mp4?dl=0

Driver game – Field test 2 (conducted in public bus):
https://www.dropbox.com/s/q29q8utu468ypqb/DriverGame_Updated.mp4?dl=0

Passenger game – preliminary field tests in Genova (conducted in public buses):
https://www.dropbox.com/s/173vap1zrpivobp/PassengerGame.mp4?dl=0

Basic social networking option in SG_CB application:
https://www.dropbox.com/s/t41wctwp5r3dj16/Social_Source.mp4?dl=0

Snake and Ladders(S&L) from SG_CB application - demonstration:
https://www.dropbox.com/s/b8tsxjakguhbuix/Snakenladders_Source.mp4?dl=0

Virtual bank option from SG_CB application - demonstration:
https://www.dropbox.com/s/1dolbh28m90kdqy/VirtualCoins_Source.mp4?dl=0

Competitions option from SG_CB application – Demonstration (screen share captured during the Gothenburg test):
https://www.dropbox.com/s/elarl2x8g1fhlpp/Competition_Source.mp4?dl=0

Final Demo - Serious games and community building application – with detailed explanation and Demo of real-time games, competitions and Event analysis of two performances:
https://www.dropbox.com/s/oo917ivpd8m3mom/SG_CB_Narrative1.mp4?dl=0